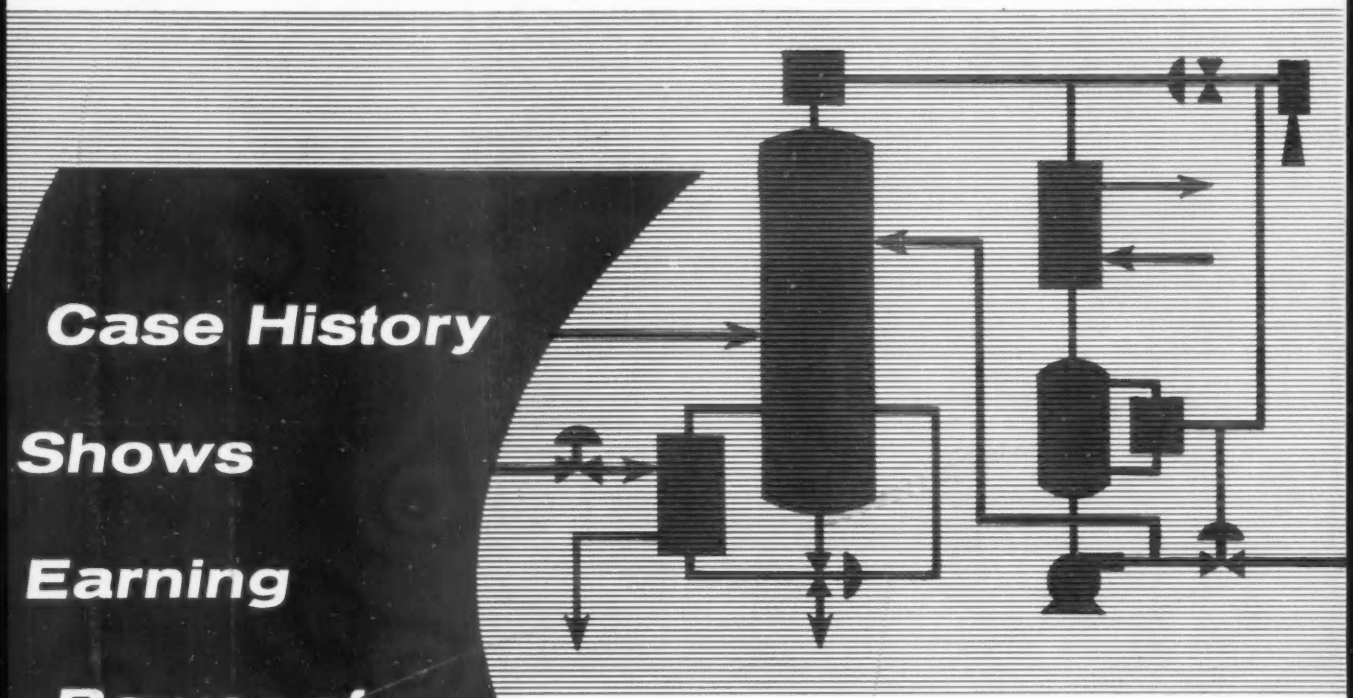
Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

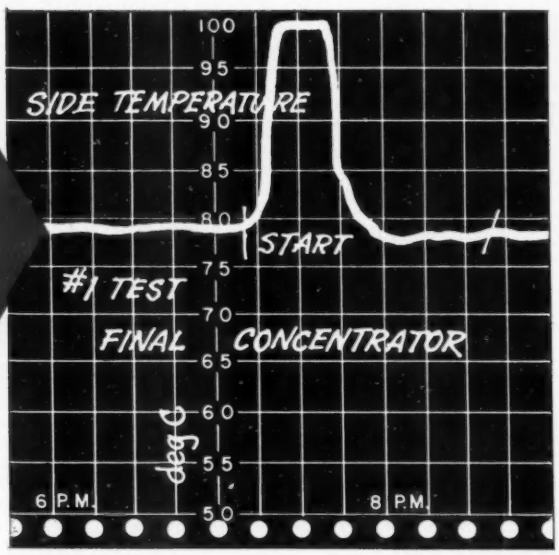
A McGRAW-HILL PUBLICATION

60 CENTS

MAY 1958



Case History Shows Earning Power of DYNAMIC ANALYSIS



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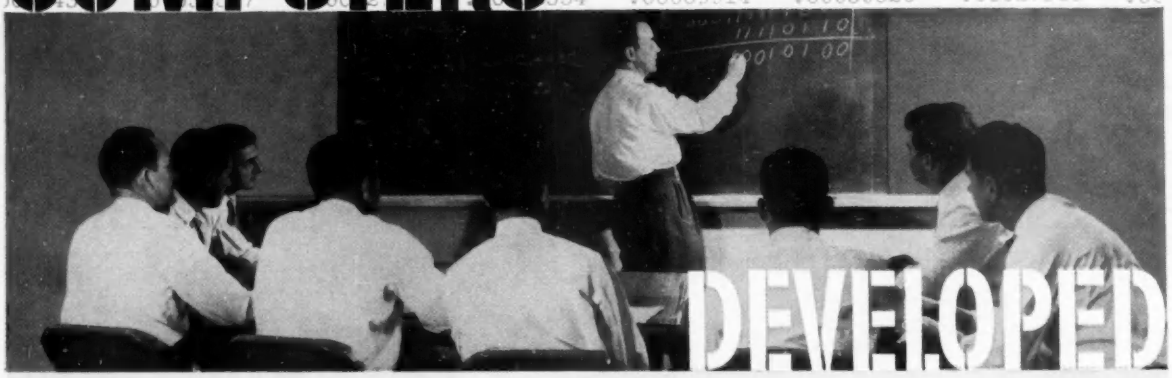

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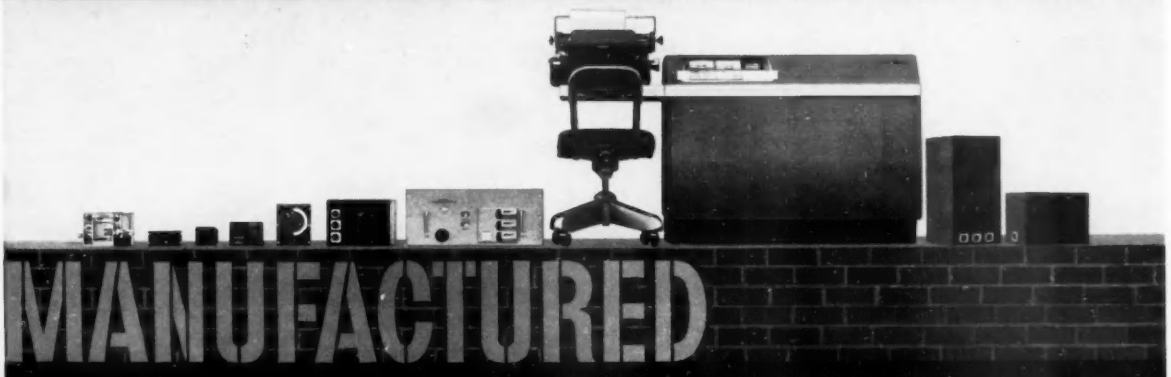

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You may not be vacuum annealing . . . but no matter what your heat treat, it'll pay you to investigate Speedomax H. Its workhorse characteristics . . . its two to four week delivery . . . and its moderate price now, more than ever before, make this null-balance controller an attractive investment.

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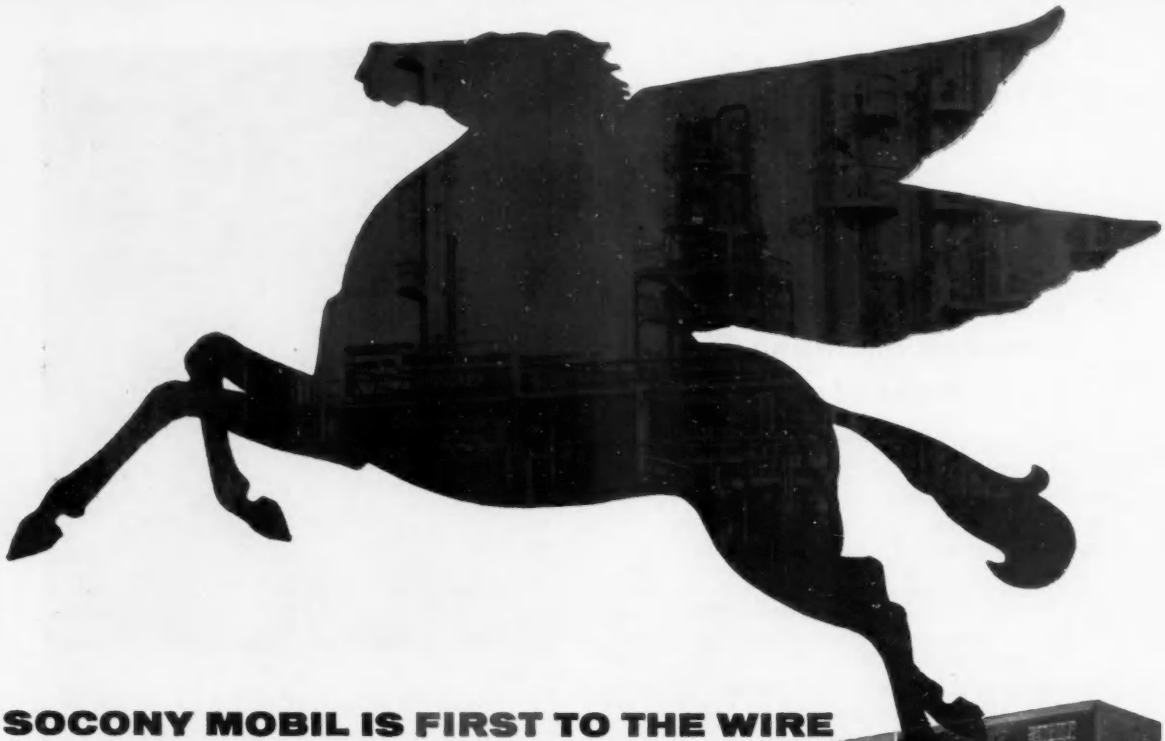

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with a major refining process chiefly dependent on an automatic data processing system...

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When Socony Mobil decided to add a new multi-million-dollar catalytic reforming unit to their existing plant at Casper, Wyoming, they played a systems favorite. They put their instrumentation money on Beckman Systems Division.

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It was the Beckman 112, designed and built for continuous, twenty-four-hour, seven-day-a-week service in the process industries.

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Systems Division

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Control ENGINEERING

MAY 1958 VOL. 5 NO. 5

Published for engineers and technical management men who are responsible for the design, application and test of instrumentation and automatic control systems

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The article on page 91 demonstrates that the decision to put Frederick A. Woods at the head of the newly formed Systems & Control Analysis Section is paying off handsomely for Union Carbide Olefins Co. Fred's experience in plant instrument engineering and in the companywide design of instrumentation and control systems for new installations, plus his BS in EE from MIT in 1947, laid a firm foundation for his present work of applying analog computers and systems and control analysis techniques to both processes and process control systems.

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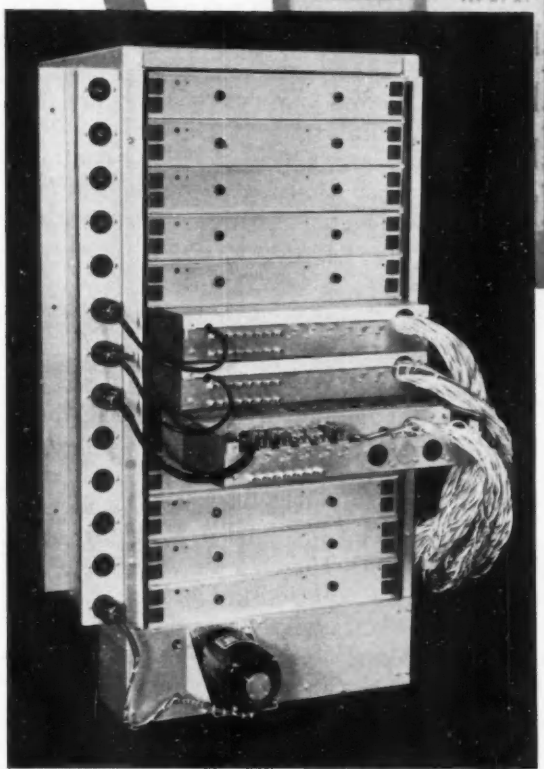

Model 1160 Oven showing component trays extended.

New Double Oven Insures Computer Accuracy

The newly-designed Beckman/EASE* constant temperature oven brings unprecedented thermal stability to passive computing elements, yielding laboratory accuracies under field conditions. Actually an "oven-within-an-oven," Model 1160 holds accuracies of .002 percent despite ambient changes of 70 to 110° F. and line voltage changes from 105 to 130 volts. Simultaneous changes in ambient or line voltage do not affect this accuracy. Naturally, as the environment improves, so does the accuracy.

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The EASE* double oven makes possible — for the first time — a computer system independent of any temperature change.

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Model 1160 Oven

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   Provides adequate room for
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   b. 80-1 μf polystyrene capacitors
2. TEMPERATURE DATA (for given environment)
   a. Set point, 45° C ± 0.05°
   b. Variation**
      1. Resistor Region,
         ±0.5° C max.
         ±0.3° C nominal
      2. Capacitor Region,
         ±0.3° C max.
         ±0.1° C nominal
3. ENVIRONMENT
   a. Ambient temperature range 70° F. to 110° F.
   b. Line voltage 105 to 130 volts a.c.

*** Variation in temperature means the maximum deviation in instantaneous local temperature due to long term drift and any combination of environment and line voltage changes within stated range.*

For further information on the Model 1160 Oven and the EASE* 1100 Series Computer, please write Dept. L5

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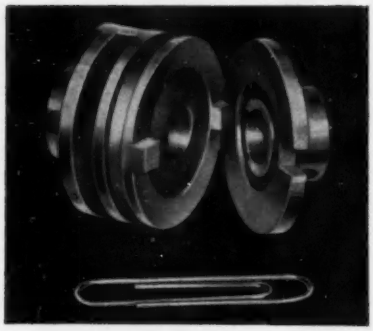
ON THE SHELF!



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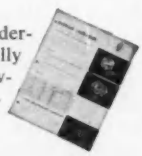

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Control around the world

This month CtE launches another new feature to further expand our coverage of international control activities. In *The World of Control*, page 19, to be alternated occasionally with the *Control Personality*, CtE's foreign editors will describe control activity in other countries, highlighting the companies, societies, universities, and personalities that are doing the sparkplugging.

European editor Derek Barlow journeyed to Belgium to prepare the first *World of Control* story. His report—spelling out how the basics are being stressed in colleges by control enthusiasts such as Prof. Jean Hoffmann—coincides with the opening of the big World's Fair in Brussels this month. Coming in future issues: stories on France, Italy, Germany, Russia, and Japan.

The pulse of Detroit automation

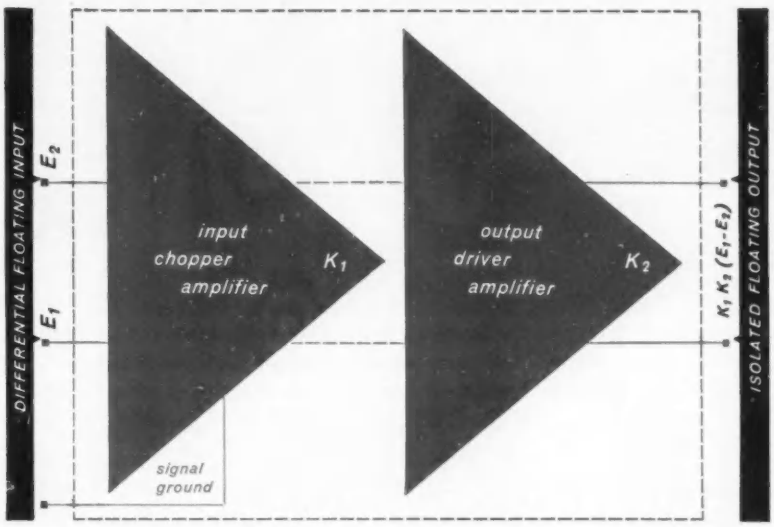
In Detroit, where the term "automation" was coined, the current sentiment of the automotive manufacturers on the increased use of automatic production equipment has been hard to define. To get a clearer picture for CtE readers, Associate Editor John Cooney spent several days in Detroit, dividing his time among the Big Three of the car industry. Austerity is the watchword, he reports; critical looks are being taken at past practices and dollars are not being spent on new control equipment without careful justification. Some of the important points John noted: interest in modular transfer machines, a cautious appraisal of numerical control, and no clearcut swing to static controls.

For all the details, see *Industry's Pulse*, page 81.

The publisher speaks

Last month, CtE's publisher Will Garey joined the editors in expounding the future of industrial control systems engineering. The occasion was a one-day conference—"Scientific Briefing for Tomorrow"—at Worcester Polytechnic Institute for the management of New England industry. Will and six other top-level men (scientists and administrators) pointed out the new technological goals for industry and the scientific programs that can make their attainment possible. Will's theme was that control systems, intelligently designed and applied, can earn money for the user. He got his point over by explaining what's meant by automatic control, by showing how the simplest feedback or switching system and the most sophisticated self-adaptive system fit the definition, and by presenting specific case histories to illustrate the earning power of control systems.

New! KIN TEL's true differential DC amplifier...



completely isolates input from output!

AMPLIFY MICROVOLT-LEVEL DATA SIGNALS New transistorized differential DC amplifiers provide extremely high common-mode rejection, very low drift, high output capability, and excellent stability and linearity... all unaffected by load or gain changes. Ideal for thermocouple amplification, they eliminate ground loop problems; allow the use of a common transducer power supply; permit longer cable runs; drive grounded, ungrounded or balanced loads, and can be used inverting or non-inverting. The 114A is the *perfect instrumentation amplifier.*

BRIEF SPECIFICATIONS – 114A DIFFERENTIAL DC AMPLIFIER

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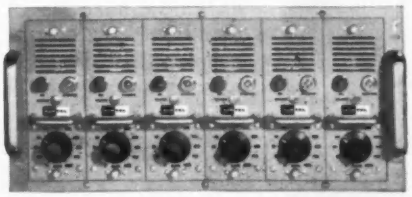
- Gain of 10 to 1000 in 5 steps, continuous variation between steps.
- Gain accuracy 1.0% DC 10 cps, 3% to 30 cps, 3 db down at 120 cps.
- DC gain stability and linearity 0.1%.
- <5 μv noise; <5 μv drift at gain of 100 or above.
- Maximum output capability 10V at 10 MA.
- 100 K ohm input, <1 ohm output Z (min. load res. 20 ohms, max. load cap. 1.0 μf).



Six KIN TEL amplifiers in compact 19" rack mountable module.

STANDARD WIDEBAND DC AMPLIFIERS can be used single-ended or for floating input applications. An operational version permits the user to employ his own feedback networks to limit bandwidth, generate transfer functions, obtain specific gains and perform integrations. Specifications for the 111 series, Wideband DC Amplifiers include: <2 μv drift; <5 μv noise. ±35 V, ±40 MA output. 100 K ohm input, 1 ohm output Z; 1.0 μf allowable output cable capacity. 0 to 1000 gain in ten steps, with continuous 1 to 2 times variation of each step. Gain accuracy (freq. response) ±1.0% DC to 2 KC, <3 db down at 40 KC.

ALL KIN TEL DC AMPLIFIERS feature integral power supplies, convenient plug-in mounting and KIN TEL's proven chopper feedback amplifier circuitry for unsurpassed stability, accuracy and reliability. They have accumulated over 500 years of operating time, and in one installation alone have logged over a million hours of trouble-free operation. Records like this are the result of stringent quality controls, thorough testing and calibration, and years of experience in the design and manufacture of thousands of chopper stabilized DC amplifiers.

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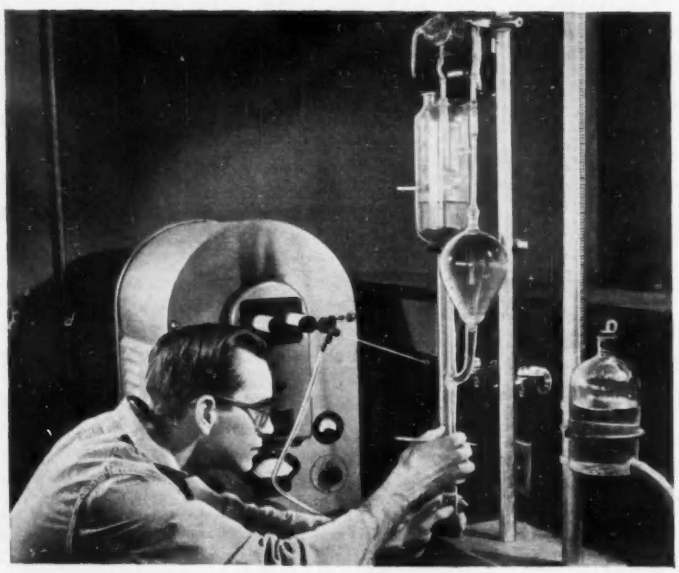
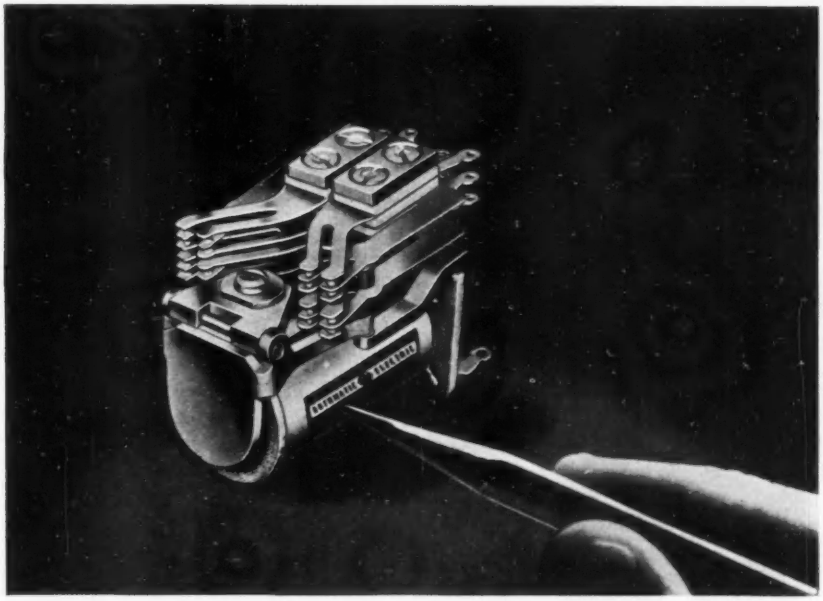
For information, call or write Automatic Electric Sales Corporation, Northlake, Illinois. In Canada: Automatic Electric Sales (Canada) Ltd., Toronto. Offices in principal cities.



Chemical analysis is one of the checks we make on our relay iron to make certain that no magnetic capabilities are lost. Annealing is rigidly controlled, and grain size and temper carefully checked. Elongation, hardness, permeability and density tests are other safeguards. All this insures a relay iron that saturates quickly, yet the flux dies out instantly. Even after millions of operations!



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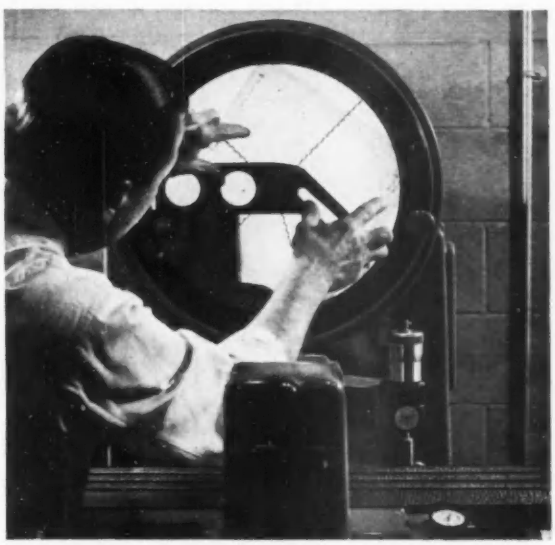

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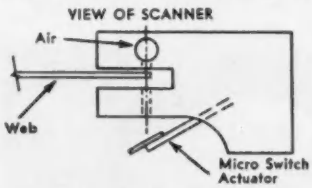
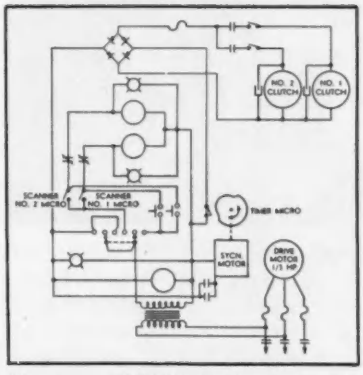
Two Warner SF-400 stationary-field electric clutch-couplings operate in opposite directions to drive a tilting bar which makes the running web of a printing press drift left or right depending on the direction of tilt. When the roller tilts, the web creeps to the high side. Control is simple and automatic. Compressed air is aimed at micro switches at either side of the web. The web blocks the air stream to both



micro switches during normal operation. But, if the web shifts off center, it uncovers one of the micro switches, which in turn is actuated by the air blast. The switch energizes the electric clutch, engaging the drive to bring the web back into line.

Electrical Schematic



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FEEDBACK

PROBLEM FORUM

An English-born and -trained engineer working in Canada, and a contemporary of his (our European Editor) discuss how the technical education system of the United Kingdom can, and does, spin off excellent technicians. The discussion was prompted by our Nov. '57 editorial, "Prepare Now for the Technician Gap".

Our invitation to you to join in the forum, at our expense, stands. The invitation still reads, "Submit a problem or start a discussion of a topic that will spread some more knowledge across the control engineering field; everyone learns while you earn".

A cure-or-kill for getting technicians

To the Editor—

While reading my initial issue of Control Engineering [Jan. '58] I noticed three letters commenting on an editorial, "Prepare Now for the Technician Gap". I would like to propose a solution to this urgent problem of lack of technicians.

In Great Britain we have, in addition to universities, technical colleges, where it is possible to obtain a technical education. These colleges are affiliated with the professional engineering societies, and the societies set the standards via syllabus and examinations. The colleges operate on a part-time basis; both lecturers and students have other jobs. Lecturers are usually university graduates employed in industry and who devote one day a week (with the permission of the firm), and maybe one night, to lecturing on a subject. The students are apprentices in engineering and are allowed one day a week on which to go to school with pay. They also must attend evening classes, usually two or three nights a week, to qualify for the day of school. Thus, both lecturer and student gain something from this system. The lecturer comes to know his subject much more thoroughly while accumulating a little extra money (though engineers in the New World may find the latter hardly necessary!). The students finds an opportunity to rise up the ladder educationally without expensive college education.

The liaison between professional society, college and employer in producing technicians thus provides immediate acceptance for the successful student by the three bodies.

Referring to standards of education, I agree with Mr. Slater that these standards should not be elementary. I myself rose up this ladder of education and am quite familiar with calculus, thermodynamics, theory of machines, structures, strengths and properties of materials, at a university level. The Great Britain course described takes six years on a part-time basis; the road is stony, but this is a necessity for the production of good technicians.

The important facet of this scheme is that at the end of the road is incorporated membership in the professional society, no less! Seventy-five percent of the students will find themselves limited by their powers of absorption and fall by the wayside. These are your technicians! By attaining the various milestones on the way to incorporated membership, though they may not reach the end of the journey, they have attained the rank of junior technician, senior technician, or professional engineer. Thus, by leaving the door open for these candidates to continue their education, you have created a happy technician satisfied with his lot and not a morose and disappointed person who feels that the only difference between himself and the professional engineer is that the latter had the money for an education.

P. Ward
Sidney Roofing & Paper Co, Ltd.
Lloydminster, Alberta, Canada

Teletype from London gives details

To the Editor—

In the United Kingdom four types of technical colleges provide a pyramid of education leading to a diploma in technology—equivalent to a university degree. There are some 200 colleges situated in most of the large towns throughout Britain. The majority of them provide courses leading to the ordinary national engineering cer-

tificate, roughly equal to the first year work of a university. Above these local colleges come area colleges where students can specialize for a higher national certificate. Then above these come eight national colleges of technology where the end product is the diploma in technology, a requisite of which is some practical work. Certain of the fourth class, regional colleges, provide education for all these categories.

The colleges act in two roles. They provide full-time day courses for students from the age of 16 upward. Lecturers are full-time. In addition to the full-time courses, students may take part-time courses consisting of one day and several evenings a week or sandwich in courses which are worked in conjunction with industry. Here the student spends six months full-time at college and the remaining six months of the year at his engineering firm. Lecturers may be part-time, drawn from industry. The setup is similar to U. S. colleges' cooperative program.

In addition to the certificates and diploma, students can aim for a variety of educational standards, i.e. external degrees from universities, or the halfway house, such as city and guilds examinations.

The technical colleges are in no way affiliated with the professional engineering societies, although the syllabus of some of the certificate and diploma courses is discussed by the Ministry of Education—the controlling body—with professional societies to ensure uniformity. The colleges are supported by grants from the ministry of education, in part, and partly from money allocated from the local town's taxes. Course fees for the students are nominal and do not provide the college's main income.

The student may become a member of a professional society by way of the technical college but this is not the main aim of the courses put on by the college.

At present some half-million students are attending part-time courses for the ordinary and higher national certificate.

While I agree with Ward's sentiment that technical colleges provide the sink-or-swim answer to the problem of technicians, I feel that the above may straighten away some misconceptions which his letter could give.

Barlow/London

Which tool should he use?

TO THE EDITOR—

At present I am interested in the advantages and disadvantages of the various techniques used in the analysis

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FEEDBACK

and synthesis of control systems such as Nyquist, Bode, and root locus. As a subscriber to CONTROL ENGINEERING, I do not recall any article in this respect or on a comparison of these methods.

The purpose of this letter is to inquire if such an article has been published in CONTROL ENGINEERING or if you can make any suggestions for references on this subject. Any information would be greatly appreciated.

L. A. Michelotti
Armament & Control
Defense Electronics Div.
General Electric Co.,
Schenectady, N. Y.

We have not published such an article, though we have published articles on the use of each method you mention. Because the most appropriate mathematical tool depends on the type of problem, and the types of problems are legion, we doubt that an article on the topic would be specific enough to have any value. There is, however, good discussion of this question in BASIC FEEDBACK CONTROL SYSTEM DESIGN, C. J. Savant, McGraw-Hill Book Co., Inc., 1958. Ed.

Sees CtE cover; suggests idea bank

TO THE EDITOR—

I was a little startled on seeing the cover of the February issue of CONTROL ENGINEERING since it depicts a multiple-ball relay which I built and tested some years ago and for which I have a patent pending at the present time. A patent search indicates that the broad idea of this type of relay is not new. My designs have certain features not shown in prior patents and the same is probably true for Mr. Ovshinsky. I shall not bother him. I might even offer him my improvments under a suitable arrangement if he is interested some time.

Research and invention have been my vocation and hobby for many years, and during that time I have recorded in my notebooks probably several thousand inventions in many fields, and also ideas for basic research. I often file anywhere from half a dozen inventions to fifty or more in one application with the idea of filing divisional applications later. In view of the heavy expense involved in filing so many applications I frequently patent one or two out of a group and leave the rest for a later day. In many cases the ones which I put aside prove to

. . . Fluid Power news

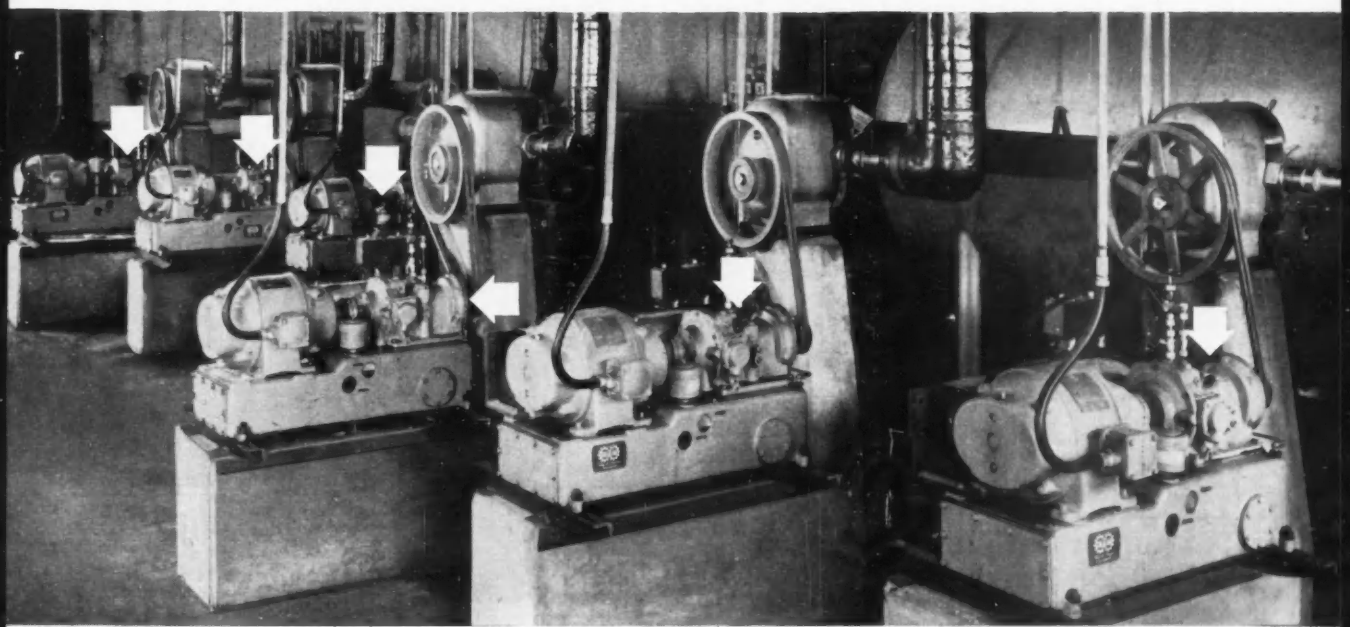
REPORT NO. 11,300 NEW LIQUID LEVEL CONTROL

From Oilgear Application-Engineering Files

HOW OILGEAR DRIVE AND CONTROL SYSTEM STABILIZED BEER FILLING LEVEL

CUSTOMER: *Large Western Brewery (Name witheld by request)*

DATA: Highly carbonated beverages must be handled gently. Throttling flow of beer into filling machine reservoirs causes foam and irregularity of liquid height, making accurate filling of cans or bottles difficult. These reservoirs are small compared to the flow through them. Costly losses are incurred on tax-paid cans "in process" due to under or overfilling. Any beer pump drive-control system must respond immediately, have smooth action, and be unaffected by daily wash-downs required to maintain sanitary operations. Accurate automatic control, dependable operation, and ease of maintenance—as always—are important factors in the selection of this equipment.



SOLUTION: Shown "on the job" above, are 6 Oilgear AHB-33, two-way, "Any-Speed" transmissions driven by 3 hp electric motors, mounted on standard reservoir bases. Transmissions drive beer pumps through dual "V" belts. Beer is pumped from storage tanks to bottle or can filling machine reservoirs on the floor above. Liquid level in filling reservoirs is controlled automatically by a low pressure CO_2 signal . . . as level rises, pressure rises . . . as level falls, pressure falls. Translated to air pressure signals, which, transmitted to controls on Oilgear transmissions, automatically-instantly increase, decrease, reverse, or stop the beer pumps. Where former throttling system caused foam and irregular levels, this Oilgear system holds reservoir level to $\pm 1/16''$ under continuous operation . . . assuring accurate filling of each can or bottle. Beer pumps are flushed under water pressure without disconnecting drives. Several years of continuous service have proven drives to be extremely dependable under all conditions, with little or no attention.

Oilgear Application-Engineering can also provide practical solutions to your linear or rotary drive problems. Call the factory-trained Oilgear application-engineer in your vicinity. Or write, stating your specific requirements, directly to . . .

THE OILGEAR COMPANY

Application-Engineered Fluid Power Systems

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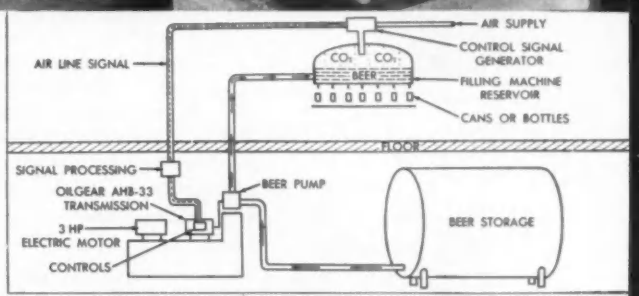

Similar Oilgear "Any-Speed" drives have improved performance on can closing, filling; paper, printing, textile, tape, and rubber processing machines; extruders, capstans, winders, stokers, centrifuges, gang-saw feeds, saw mill carriages, conveyors, and the like. They provide efficient conversion of any constant rotary motion to accurately controlled variable rotary motion . . . smooth, stepless, uniform acceleration from zero to maximum in either direction . . . manual, hydraulic, electric or electro-hydraulic controls—providing complete flexibility of location . . . low power consumption—using power only in proportion to work performed . . . durable, trouble-free, low maintenance due to simplicity and automatic lubrication of all rotating parts.

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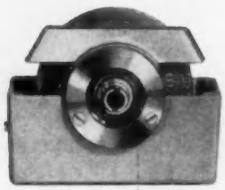

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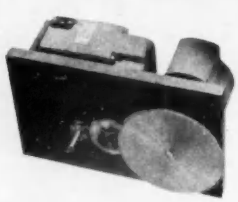

CG-200 Series

DATEX ENCODERS are characterized by their large number of positions per 360° rotation. Models having 1,000, 2,000, 2,048 counts per revolution are illustrated. All models are brush type units with the brush continually in contact with the disc. Thus readout "on the fly" is possible and readout or sampling of the encoder can be done at frequencies from DC to over 100 KC.

MODEL C-100 Series – 4" x 4⅝" x 3⅛". Over 100 different calibrations available to fit popular models of Recorders without gearing. Non-linear calibration for temperature and flow. Up to 1400 positions per 360° rotation. Low Inertia Models also available. Hollow shaft ⅜" opening facilitates mounting, and adapter kits are available to fit many models of strip chart Recorders.

MODEL C-900 Series – 6½" Diameter. This series features up to 2,048 positions per 360° rotation. Hollow shaft, ⅜" opening facilitates mounting. Available in other configurations to suit application. Inertia 4200 gmcm², Torque 1.5 oz. in. Available in Gray[1], DATEX and other special codes.

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(1.) In order to provide Binary information from Gray code, a high speed continuous output Gray-to-Binary Transistorized Translator is available.
(2.) Readout devices to operate from these encoders are available from DATEX.®
Write for Bulletin 312.

GIANNINI DATEX® DIVISION
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FEEDBACK

be of considerable importance later.

My experience with patents has led me to believe that we need to revise our patent system to bring out the hidden inventions for public use. Some years ago a committee in Washington asked me to suggest improvements in the patent system. One of these suggestions—the printing of reference patents on copies of issued patents—was adopted. I was asked again about two years ago to make a study of the patent system and to recommend improvments.

Some of the suggestions I made are:

1. Establish a register of ideas in which inventors can record their inventions and ideas to establish an unquestioned date of priority. Then allow a two-year period for the inventor to apply for a patent or patents or to interest another party in buying the invention or in advancing expenses for patenting. At the end of the two-year period the government could patent the invention if this has not been done, thereby acquiring an interest. This program could be self-supporting due to patent sales by the government. A register of this kind would encourage prompt disclosure of inventions for the public benefit and would provide an unquestioned date of priority. A small charge for entering ideas in the register could be made by the government.

2. One serious deficiency of our present patent system is that it often affords little actual protection to an inventor if his rights are violated. Litigation is so costly and so long drawn-out that many inventors are in no position to challenge an infringer regardless of the merits of the case. In order to alleviate this condition, I propose that the patent office sell patent insurance which will provide an inventor with the necessary funds for prosecuting infringers or for defending himself in case he is sued. The cost of this insurance could be added to the cost of patents since the insurance system will benefit all independent inventors by engendering a respect for patent rights.

3. It would be helpful to set up an advisory board in the patent office to provide advice for inventors, for a small fee. This board would be particularly useful in guiding inventors regarding the advisability or merits of claiming patent insurance for filing or defending patent suits.

A. G. Thomas
Butler, Pa.

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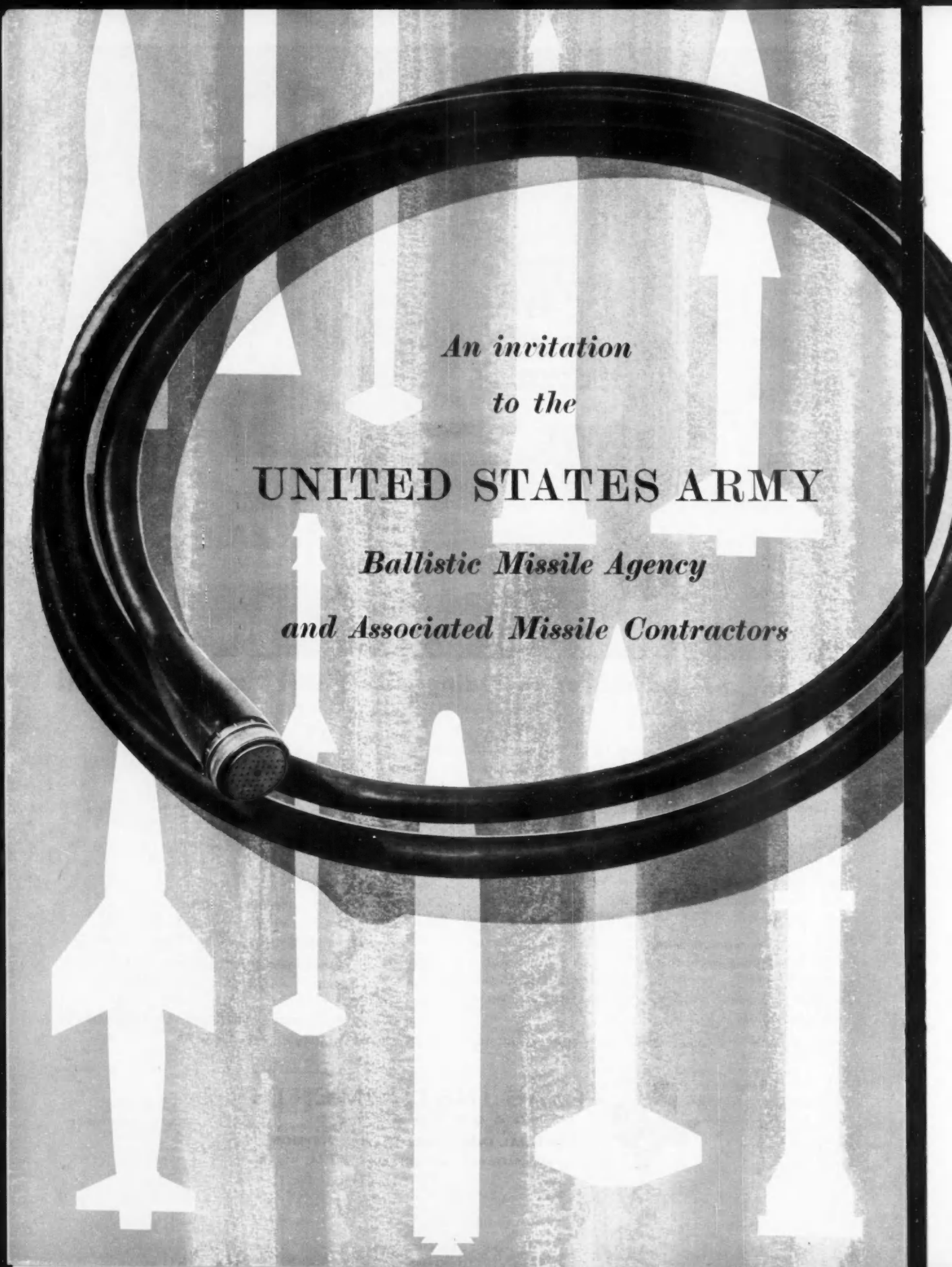
An invitation
to the
UNITED STATES ARMY
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INVITATION: This is an invitation to utilize the missile systems engineering services of Pacific Automation Products, Inc., on current and upcoming Army missile programs.

QUALIFICATIONS: PAPI is an organization of 700 cable systems specialists. Over 150,000 square feet of floor area are now devoted to engineering, manufacturing, inspection, with production capacity to meet any workload. Because PAPI cables have been used on such Army missile programs as the Sergeant, Hawk, and LaCrosse, you know our product to be reliable.

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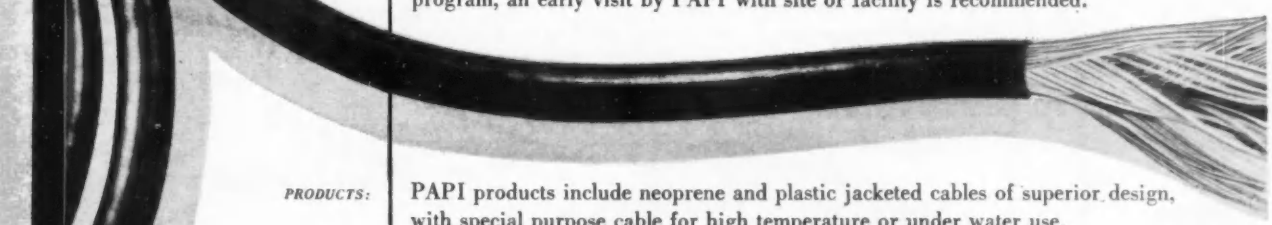
So that this experience may be used to full advantage on each Army missile program, an early visit by PAPI with site or facility is recommended.



PRODUCTS: PAPI products include neoprene and plastic jacketed cables of superior design, with special purpose cable for high temperature or under water use.

SERVICES: PAPI offers the following services in the cabling and activation of missile test and launch facilities: *Systems Design*—working from schematics, PAPI design engineers will determine every conductor that is needed to link block houses, control centers, terminal rooms, and stands or platforms. Cables are designed to effectively accommodate these conductors, and include break outs, connectors, and accessories. *Systems Fabrication*—cable assemblies leave our plant in ready-to-install condition, with rigorous quality control procedures governing every step of the fabrication process. *Systems Installation*—PAPI's experienced personnel and proven methods are utilized in field installation of all inter-unit cabling, instrumentation, recorders, transducers, controls, consoles, and accessories. *Systems Checkout*—PAPI specialists checkout all circuits for conformity to specifications, confirm the operation of each instrumentation system, and validate the fire and launch control functions. *Systems Documentation*—working drawings of the entire installation are supplied in approved form.

CONCLUSION: PAPI's engineering staff includes men with outstanding experience in every pertinent phase of the missile business. It is no accident, therefore, that we are the "take charge" sort of people who can take full responsibility for providing the services described in this message. We hope that you will accept this invitation and plan to utilize PAPI's great practical knowledge and experience in Army missile facility cabling and activation.

Arthur P. Jacob

ARTHUR P. JACOB, EXECUTIVE VICE PRESIDENT

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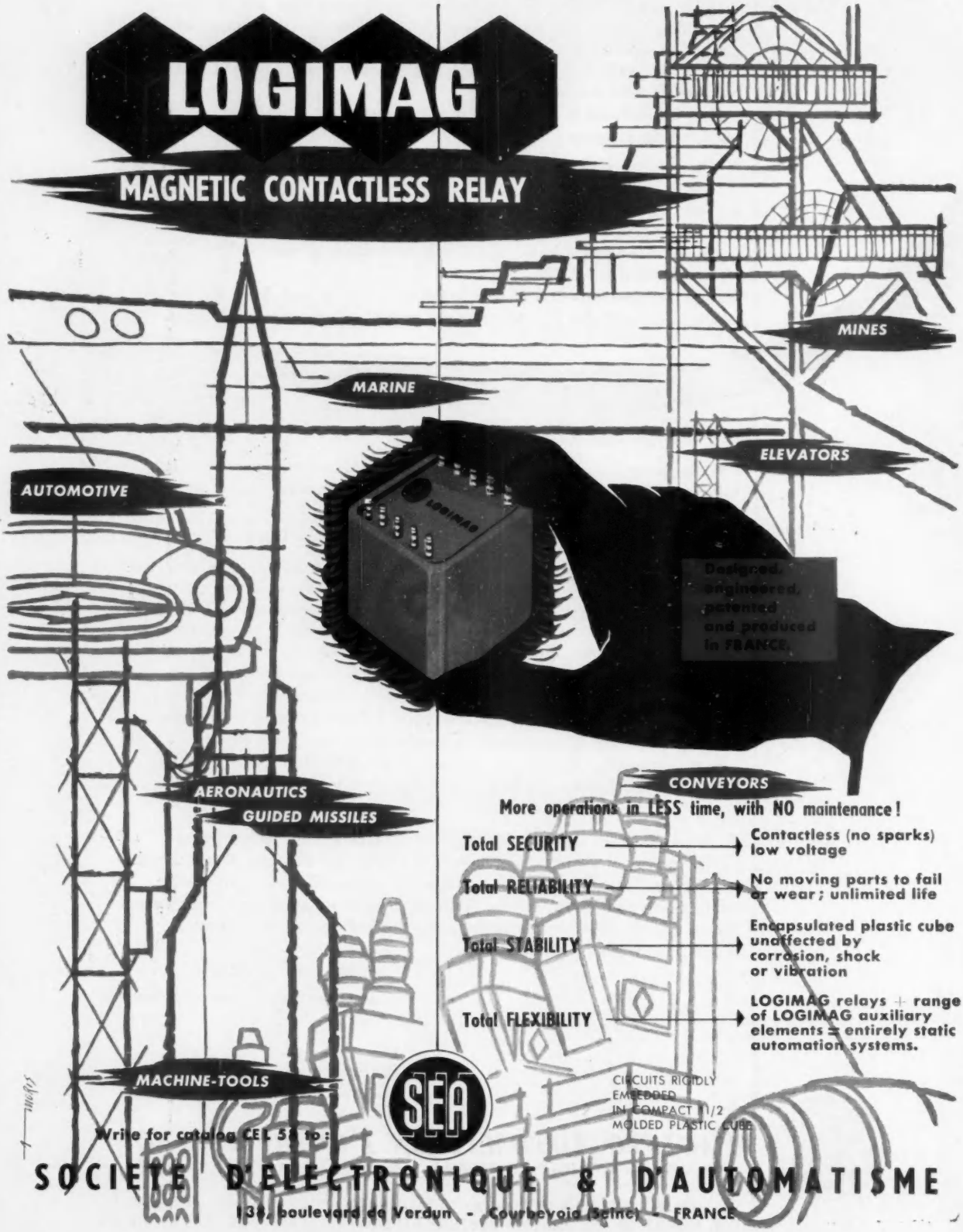

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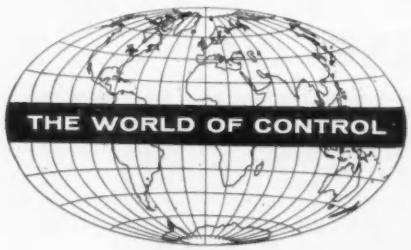


BELGIUM

Building Basics on the Campus

In May, Belgium will start playing host to the world at an international exhibition that will last over the summer and into the autumn in its capital city of Brussels. Along with hospitality, the Belgians will show off their young but growing control industry. Visitors interested in this aspect of engineering will find that the basics of Belgian control technology are grounded in the campuses of 4 universities.

Three years ago only a handful of people realized the importance of teaching and research in the control field. From this handful was born IBRA–Institut Belge de Regulation et d'Automatisme. One of its aims was to put control on the curriculum of Belgian Universities. To do this it first had to start its own courses at centers throughout Belgium like Ghent, Antwerp, Liege, Charleroi and Brussels. But now, IRBA's dynamic administrator, Max Ajnbinder, who spearheads this work, sees

LOUVAIN UNIVERSITY: systems response in medieval aura.

success in four of Belgium's leading universities.

Set at the corners of a 50 mile square, Brussels, Liege, Louvain and Mons form the heart of Belgium's control theory. Of these, Brussels and Louvain are privately endowed while the government supports Mons and Liege. Throughout the control picture, close cooperation between the universities and industry is maintained, and industry research supports a large percentage of university engineering activities. In size, tiny Belgium (total population only nine million) cannot hope to compare with U. S. universities, but courses are rugged, qualifications high. Belgium's 365 engineers a year are graduated after five years continual intensive study.

LIEGE UNIVERSITY: closed loop transfer functions.

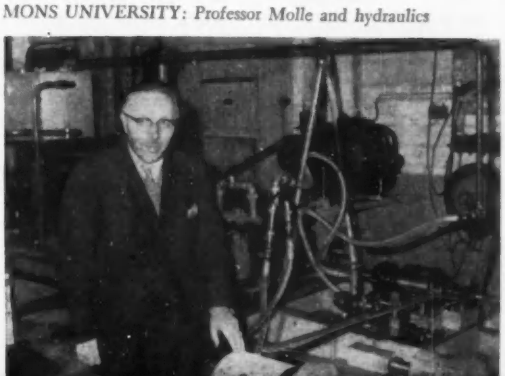
At the Prince of Arenberg's former castle–now the hub of Louvain University founded in 1425,–a former Cal. Tech. graduate is building up control theory courses prior to research. M. Van der Waeteren, under his professor, M. Van Cauteren, aims to provide a firm grounding for his 60 students a year in analog computers and engineering cybernetics. Included in this will be system response determination and non-linear systems. Eventually Van der Waeteren hopes to extend this to industry research activities. He is building up experimental control panels and heat exchangers ready to simulate industrial problems.

While Louvain is edging into the process control field, the university of Mons–an old Roman town where each June, the dragon Doudou is slain to mark the triumph of good–ebullient Professor Molle is making good with a research program embracing hydraulics, machine tool control and high pressure pneumatics. Molle's hydraulic work on the transient behaviour of various pumps includes studies of the economic factors of each type, as well as fluid friction and hammering effects.

On machine tool control he is obtaining accuracies of 0.007 ins. on a pneumatic copying machine by pulsating the supply to a newly developed free piston pneumatic bridge. The air supply to the bridge divides into two paths with a floating free piston between the paths taking up an equilibrium position. An eccentric cam varies the pressure cycling every three seconds in one arm while the sensing head following the template alters the secondary arm pressure. Movement of the piston to balance the pressure actuates contacts controlling the work carriage drive motor.

In pneumatics, Molle feels that having solved the problem of producing a dry high-pressure air supply, high pressure pneumatic control systems may be a thing of the future. Using a diesel motor as a compressor gives him in one stage pressure of 490 psi. Overcoming moisture problems by expansion

MONS UNIVERSITY: Professor Molle and hydraulics



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1 PHASE POWER SOURCE (NOTE 1)	2502	120	3.9	37	.105	350	4	.013	.0011	.0030	13	.0027	.5	290	1200	2.4	0.58	70	0.12	2502
	2503	120	6.7	43	.155	275	4	.023	.0019	.0025	26	.0047	.5	300	2700	2.0	0.58	58	0.12	2503
	2504	120	13	43	.30	145	5	.038	.0015	.0063	46	.0037	.6	340	2050	2.5	0.73	54	0.15	2504
	2505	120	23	46	.50	92	5	.057	.0023	.0060	62	.0055	.6	400	3940	2.4	0.73	66	0.15	2505
	2506	120	47	50	.94	53	5	.098	.0039	.0060	95	.0094	.6	480	7850	2.4	0.73	73	0.15	2506
	2507	120	80	53	1.5	35	7	.125	.0026	.0049	67	.0059	.7	640	16300	1.0	0.92	28	0.18	2507
	2508	120	130	57	2.3	25	7	.17	.0035	.0049	82	.0080	.7	760	26500	1.0	0.92	30	0.18	2508
	2509	120	190	58	3.3	18	8	.24	.0037	.0071	84	.0083	.75	800	26800	1.1	0.92	30	0.18	2509
	2510	120	280	60	4.7	12	8	.33	.0051	.0080	104	.0115	.75	850	35000	1.3	0.92	34	0.18	2510
3 PHASE POWER SOURCE (NOTE 2)	2522	240	19.5	110	.177	620	5.5	.035	.0015	.0180	6	.0037	.4	520	1080	7.2	0.58	210	0.12	2522
	2523	240	35.4	125	.283	440	5.5	.053	.0021	.0150	11	.0055	.4	620	2360	6.0	0.58	175	0.12	2523
	2524	240	65	130	.50	260	7	.081	.0016	.0415	18	.0041	.5	830	1560	8.5	0.73	180	0.14	2524
	2525	240	125	135	.93	145	7	.14	.0028	.038	26	.0068	.5	900	3300	7.8	0.73	220	0.14	2525
	2526	240	237	142	1.67	85	7	.22	.0045	.0415	38	.0112	.5	1100	5700	8.5	0.73	230	0.14	2526
	2527	240	355	165	2.15	77	8.5	.27	.0038	.0225	35	.009	.6	1300	15750	3.1	0.92	90	0.18	2527
	2528	240	550	173	3.19	54	8.5	.37	.0051	.0215	42	.0123	.6	1500	25500	3.0	0.92	90	0.18	2528
	2529	240	770	176	4.37	40	10	.48	.0048	.830	38	.0111	.7	1600	25800	3.3	0.92	90	0.18	2529
	2530	240	1170	180	6.53	28	10	.60	.0060	.030	42	.0139	.7	1800	39000	3.9	0.92	105	0.18	2530

1. Type DD1B amplifiers (Bulletin Numbers 2502-2510) operate from a 60 cycle, 1 phase power source, and consist of 1 reactor, 2 saturating rectifiers, and 1 complementary rectifier. (See Note 6.)
2. Type DD3B amplifiers (Bulletin Numbers 2522-2530) operate from a 60 cycle, 3 phase power source, and consist of 3 reactors and 6 saturating rectifiers.
3. Basis of Ratings—
   Reactor—50° C temp. rise above a 40° C ambient
   Rectifier—40° C temp. rise above a 35° C ambient
4. The time constant for any value of resistance in the control circuits can be determined as follows:
   $$TC \text{ (in cycles)} = C_1 \frac{N^2}{R} + C_2$$
5. Additional or special control windings can be supplied. Bulletin Numbers 2502, 2503, 2522, and 2523 require special terminal brackets for more than 3 windings. Other 2500 Series amplifiers require special terminal brackets for more than 4 windings.
6. DD1B amplifiers can be supplied as AD1 (AC output) amplifiers. Current and voltage outputs (RMS) are approximately 1.3 times, and AC power is approximately 1.7 times, DC values shown above.

- **Other output and supply voltages available.**
- **Standard low input amplifiers (10^{-9} watts) and standard high output amplifiers (4.5×10^6 watts) are also available.**

Send for your copy of Bulletin 1105-1, a new 32-page bulletin on magnetic amplifiers, giving principles, characteristics, circuits and construction. Please make request on your company letterhead.

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drying, he visualizes that controllers and actuators could give greater powers with smaller sizes.

Although all Belgium universities foster industrial research, Professor Gilbert Burnay has put Liege University at the top of the list for industry-university cooperation. Dealing mainly with heating and air-conditioning, Burnay's entry into the control field has been indirect, springing from his work and that of his assistant Jacques Vidal on rheoelectric analogs for heat transmission studies. Here servo design by Vidal led to fully automatic field plotting with a digital readout of field gradients. From there Vidal moved to closed loop transfer function determination. His aim—to build up a library of transfer functions for various items of control hardware as a first step in providing a system analysis service for industry. As part of this, Vidal's immediate project is the design of a frequency analyser operating from transient data inputs.

Rounding off the university quartet is Brussels whose control work under Professor Hoffmann (see below) centers around analog computation. Originally most of the work was on electrical transmission networks.

Professor J. Hoffmann

builds and rebuilds

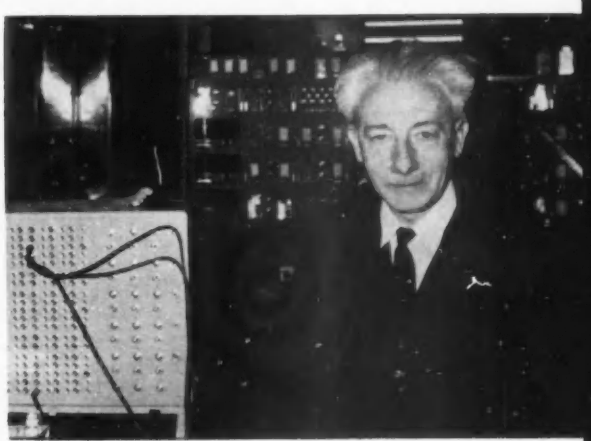
To return to your homeland after an enforced absence and face the destruction of your life's work requires courage. This is what Professor Jean Hoffmann had to endure on his return to Belgium after 39 months in German concentration camps. Now, 13 years later, Hoffmann has carved out a second career, one that spans all facets of Belgian control activities.

Returning to the University of Brussels in 1945, Hoffmann found the laboratories where he had worked from 1928 onwards had suffered little from the German occupation. But they needed new equipment. He built some himself, borrowed money to buy others and then earned money with student assistance by building equipment for the reviving Belgian industry. Watching Belgian industry rebuild. Hoffmann envisioned the emergence of automatic control as a separate subject.

So a year later in 1946, he extended his curriculum, founding at the University of Brussels the first laboratory for industrial electronics in Belgium. Here his pre-war work on electrical networks steered his interest to the use of analog techniques for network synthesis. From this, Belgium's first analog computer and later a computer service came into being.

Hoffmann's role of a control builder is a practical one as well as pedagogic. In 1930, while an assistant in the electrical engineering labs, his interest in transient behaviour of alternators started him in the regulation field by building a thyratron voltage controller for a 60 kw alternator, still in use today. In the intervening pre-war years an automatic coupling system for synchronous motors and an electric flywheel for checking transient characteristics were two of Hoffmann's achievements.

But in 1955, the realization that brainpower as well as practicability was needed, turned Hoffmann towards association work. Hoffmann says "In Europe we have not the money for all the equipment needed. To buy anything is a drama multiplied by a tragedy, so we have to make good with brain-power. But to attract the brain-power we must first tell them what control is about." This Hoffmann did so well, that in 1955, after his second information course for industrialists on analog



computers, the International Association of Analogue Computation came into being. From an initial membership of 100 it has grown under the two years of Hoffmann's presidency to 500 strong, representing 22 countries. At present, Hoffmann is hard at work organizing its second international convention to be held this September, in Strasbourg.

This was just a start. When the Belgium's Institute of Automatic control (IBRA) was formed Hoffmann was elected its first vice-president; and in September, 1957, he was in Paris as the head of the Belgian delegation voting for the formation of IFAC—The International Federation of Automatic Control.

Now Hoffmann is ready to begin still another stage of his plan for control education. This involves the creation of an automatic controls research laboratory at Brussels University to be jointly supported by the Mechanical Engineering Dept. of the university and industry. To him, it's one more milestone on the road back.

Soviet Computing Machines

Smallest computer in use in the U.S.S.R. is this continuous-action analog machine, the MN-M. A new design, the MN-M relies entirely on semiconductor devices. It can handle nonlinear differential equations up to sixth order. Other analog computers currently in quantity production in Russia are the IPT-5, the MPT-9, the MN-7 and the MN-8. Soviet scientists are using them to solve a variety of mathematical and logical problems, as well as a wide range of simulation problems.

Ed. Note: Visitors to the Belgian World's Fair will be able to see this machine in the Soviet Pavilion.

Business data electronic tabulator T80-102 is designed primarily for mechanical accounting, statistical calculations and planning; but it can also be used for mathematical, astronomical and scientific calculations in place of the T-5 tabulator. The T80-102 performs algebraic additions, subtraction, multiplication, division and other logical operations. Input data is supplied on 80-column punched cards and the output is paper punched tape. The machine handles up to 300 cards per minute.

Ed. Note: This appears to be quite similar to U.S. machines like the IBM 604 electronic data processing machine. Both the Russian and the IBM machine are plug-board programmed. One apparent difference: less concern over esthetic appearance and industrial design in the Soviet machine.

Aid to Soviet metalworking industry is this new instrument, the VPRR, designed to determine the best operating conditions for metal-cutting tools. It selects the most efficient mode of operation to make best use of the capacity of the machine and the cutting tool material.

Ed. Note: This device resembles closely, in appearance and function, the machinability computer developed by the Carboloy Dept. of General Electric about three years ago.

This electronic harmonic analyzer, the GA-2, replaces a mechanical manually-controlled device. Soviet scientists report it has markedly decreased operator errors in analyzing harmonics in graphically set functions. The GA-2 was designed as part of Soviet participation in the International Geophysical Year. It's first use: to analyze IGY data on mechanics, resilience theory, oscillation theory, and areodynamics.

Convair launches a 1,600 hour course to train aircraft instrument technicians in data processing, telemetry, and fundamental instrumentation. The reason: there's only one technical institute in the country turning out technicians with adequate training.

Aircraft Instrument Technicians:

Scarcer and Harder to Train

The suitcase display (below) of the instrumentation data gathering system for a high altitude, high Mach number military airplane shows how complex aircraft instrumentation has become. Accompanying such growth is the worsening problem of obtaining adequately trained instrument technicians. That's why at the Convair-Fort Worth Div. of General Dynamics Corp., an instrument technicians school was established. And last month, plans were afoot to add 1,200 hours of advanced flight test instrumentation training to the program.

Frank Balik, general foreman of instrumentation in the Development Field Operations Dept. at Convair-Fort Worth, tells what's happened in his own department. Four years ago there were 120 instrument mechanics in his group, working with the devices applicable at the time—primarily visual instruments, oscillographs, recording equipment and camera equipment. Of the 120, only four were highly skilled in electronics; 12 were electrical technicians.

But now Balik's department employs 500. He uses 121 skilled electronic technicians and needs more.

And the instrumentation technician's job, says Balik, has changed. Job requirements for an instrumentation research and development technician, as detailed in Convair's job description, reads:

"This occupation requires the application of electronic theory and research techniques to design, develop, construct and evaluate details involved in the original application of electromechanical devices and electronic circuits for ground and airborne instrumentation systems".

To meet this changing scene, Convair last year expanded its existing training program, added basic electronics. That brought the program to eight phases, each consisting of 50 hours of instruction. The phases:

Phase I, electrical fundamentals; phase 2, magnetism and measuring devices; phase 3, ac fundamentals and inductance; phase 4, fundamentals and capacitance; phase 5, power supplies; phase 6, amplifiers and oscillators; phase 7, transmitters; and phase 8, receivers.

But even this apparently basic training didn't seem to be enough; Convair felt that the employee should have some formal education in flight test instrumentation. Now the Instrument Dept. is readying an additional four phases of training that will add 1,200 hrs to the program.

The four new courses as outlined by Convair:

- Instrumentation training including 225 hrs of study in general instrumentation. Specifically, the course will include 25 hrs in physics, 75 in measuring devices, and 125 in electronic test equipment.
- Recording training, totaling 375 hrs. Of this total, 39 hrs will

Suitcase display brings a variety of equipment to the classroom.

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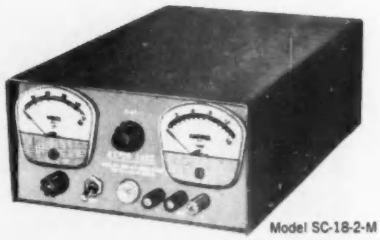

Model SC-18-2-M

VRPS*

0.1% REGULATION and STABILITY

*Two units mounted in Rack Adapter RA-2

(TUBELESS)

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Model SC-18-4-M

* VOLTAGE REGULATED POWER SUPPLIES

MODEL	OUTPUT VOLTS DC	OUTPUT AMPERES DC	OUTPUT IMPEDANCE DC-1KC	OUTPUT IMPEDANCE 1KC-100KC	SIZE W	SIZE H	SIZE D	PRICE
SC-18-0.5	0-18	0-0.5	.04	.4	8⅛"	4⅛"	13⅝"	$195.00
SC-18-1	0-18	0-1	.02	.2	8⅛"	4⅛"	13⅝"	250.00
SC-18-2	0-18	0-2	.01	.1	8⅛"	4⅛"	13⅝"	295.00
SC-18-4	0-18	0-4	.005	.05	19"	3½"	13"	395.00
SC-36-0.2	0-36	0-0.2	.1	1.0	8⅛"	4⅛"	13⅝"	275.00
SC-1836-0.5	18-36	0-0.5	.08	.8	8⅛"	4⅛"	13⅝"	250.00
SC-1836-1	18-36	0-1	.04	.4	8⅛"	4⅛"	13⅝"	295.00
SC-1836-2	18-36	0-2	.02	.2	19"	3½"	13"	395.00
SC-3672-0.5	36-72	0-0.5	.15	1.0	8⅛"	4⅛"	13⅝"	295.00
SC-3672-1	36-72	0-1	.08	.8	19"	3½"	13"	395.00

Patent Pending

A 0.01% SERIES IS AVAILABLE IN 13 NEW MODELS

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- **REGULATION** (for line or load) 0.1% or 0.003 Volts (whichever is greater)
- **RIPPLE:** 1 mv. rms.
- **RECOVERY TIME** 50 microseconds
- **STABILITY** (for 8 hours) 0.1% or 0.003 Volts (whichever is greater)
- **TEMPERATURE COEFFICIENT** 0.05% per °C. Ambient operating temperature 50°C maximum. Over-temperature protection included. Unit turns off when over-temperature occurs.
- **SHORT CIRCUIT PROTECTION:** NO FUSES CIRCUIT BREAKERS OR RELAYS! Designed to operate continuously into a short circuit. Returns instantly to operating voltage when overload is removed. Ideal for lighting lamps and charging capacitive loads.
- **OVER CURRENT CONTROL** can be set from 0 to 120% of full load.
- **REMOTE PROGRAMMING** at 1000 ohms per volt.
- **REMOTE ERROR SIGNAL SENSING** to maintain stated regulation directly at load.
- Suitable for square wave pulsed loading.
- Continuously variable output voltage without switching.
- Either positive or negative can be grounded.
- Units can be series connected.
- Power requirements: 105-125 volts, 50-65 cycles. 400 cycle units available.
- Terminations on front and rear of unit.
- High efficiency. Low heat dissipation.
- Compact, light weight for bench or rack use.
- Color: grey hammertone.

ORDERING INFORMATION:

Units without meters use model numbers indicated in table. To include meters add M to the Model No. (e.g. SC-18-1-M) and add $30.00 to price.

*Rack adapter for mounting any two 8⅛" x 4⅛" units is available. Model No. RA2 is 5¼"h x 19"w, is $15.00

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be devoted to magnetic recording theory, 276 to tape recording systems, and 60 to oscillograph recording equipment.

▶Telemetry courses: 253 hrs., including 24 in telemetering theory, 100 in airborne systems, 96 in ground systems, and 33 in support equipment.

▶Data processing courses totaling 347 hrs make up the final phase to be added. Again, the course starts with theory (24 hrs). The rest of the time is spent in studying data reduction components (112 hrs), readout and recording methods (221 hrs).

In setting up for these additions, Convair found that adequate textbooks were unavailable. So, instructors—all Convair employees, mostly flight test engineers, test laboratory engineers, and qualified technicians within the shop—will prepare a specialized textbook.

All 12 phases (total: 1,600 hrs) of this course are taught at the Fort Worth Technical Institute.

Convair is bearing the brunt of the preparation costs (the courses were set up under the Smith-Hughes Acts) but employees who take the courses contribute, too. A Convair employee taking a course pertaining to his job pays 15 cents per hour; courses not directly related to the employee's job cost him 30 cents per hour.

Instrument Foreman Balik says the ultimate goal of the program is a curriculum which would be the basis of a college degree. After completing the technical course, in the visualized setup, the employee could take courses in the humanities from area colleges and receive a degree.

But the immediate aim of the course is to help solve what Balik calls his biggest problem; "finding skilled instrument technicians". And that points up a problem that's been plaguing a lot of control users: there are too few technical institutes to train technicians (CtE, Nov. '57, p. 93).

At present, says Balik, there's only one school turning out technicians with anywhere near the training required. That's the DeVry Institute in Chicago. And competition for DeVry graduates is fierce, stemming from other industries as well as the aircraft companies. Balik finds that even DeVry graduates need additional aircraft training and must be brought up to date on recent developments.

Convair expects its own technician training school will insure a source of adequately trained men (by the highly desirable process of upgrading present employees). Even more important, the aircraft company can be sure that the training is kept current.

—Kemp Anderson
McGraw-Hill News

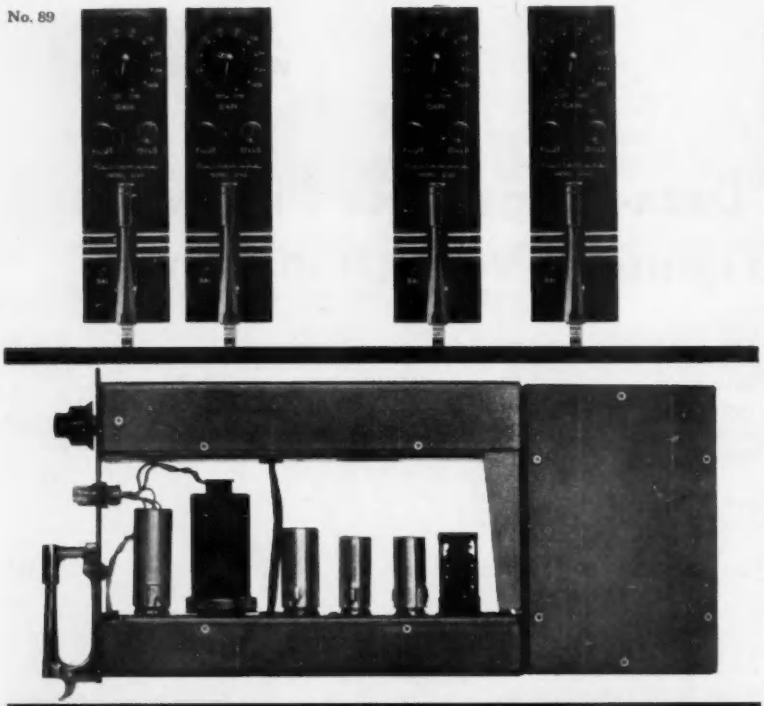
"Data-Logger" For Piecework Tightens Production Control

Dispatcher transfers day's production records to punched tape. Monitor cabinet containing communication equipment and chart recorder is in center. Close-up shows panels for individual machines. An interesting allied benefit is that the panel can indicate misuse of a machine. For example, a production rate far above the norm may indicate that a safety circuit has been bypassed.

As production engineers well know, the shop that is "on piecework" has some pretty special problems of its own. The worker has his wages tied to his output and is touchy about time lost for machine repairs, set-up, and checking. At the same time, the company has the problems of determining the outputs of individual machines for accounting purposes, scheduling production of both machines and operators, and keeping a lookout for the one or two loafers who slow the output of a costly machine. These factors account for the comparatively large number of foremen needed to keep a piecework shop running smoothly.

Long experienced in this type of operation in its role as a supplier to the automotive industry, Hancock Industries, Inc., has designed a central monitoring system that solves many of the problems outlined above. Hancock has borrowed from process-industries' control technology by regarding a multiplicity of individual machines as a single system and linking the units in the system to a central control. In the monitor room, data is provided in visual form for accounting and production control personnel. The approach has proved so successful that Hancock has set up the Control Systems Co. to market the equipment to other manufacturers.

With a Telecontrol installation, supervisors work in a central dispatch room linked electrically to every piece of production equipment in the shop. The display board includes one monitor cabinet and as many control cabinets as are needed (one for every group of 20 machines). In Hancock's Jackson, Mich. plant, where the first system is in operation, 200 machines



"BUILDING BLOCK" APPROACH SPEEDS SYSTEM DEVELOPMENT

Based on extensive experience in system development, Hallamore has designed DC Amplifier HEC-0142, for wide application in "building-block" type instrumentation systems. Combining high stability, broad bandwidth, with low noise and drift characteristics, the amplifier, one of the series of Hallamore "building-blocks," is designed to save initial development time, as well as to simplify functional changes or replacement of units within a system. *Write for complete information on HEC-0142 and the "Building-Block Instrumentation Series": Dept. 15J, 8372 Brookhurst Avenue, Anaheim, California. TWX Code: AH-9079.*

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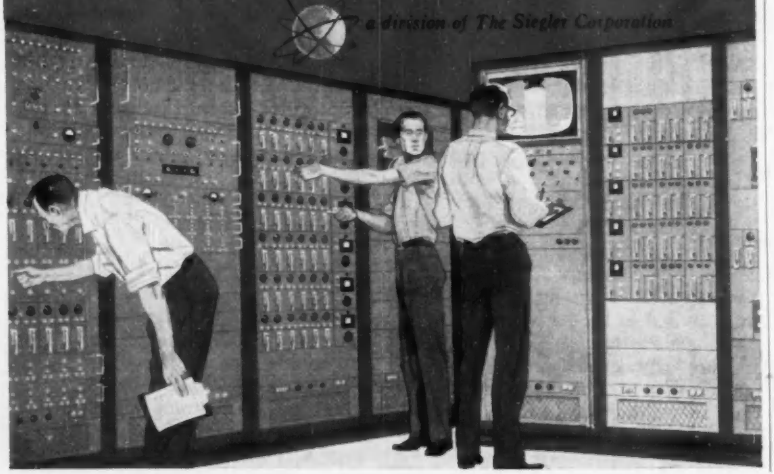


WHAT'S NEW

are connected into the system.

Each machine or sub-assembly line has a control box for signaling the dispatch room. This box has two lights, a switch, a reset button, a lock, and a telephone jack. Both lights are duplicated on the corresponding panel within the control room. In normal production, only a green light is on; but when an operator needs help from his foreman, he pushes an alarm switch to start a red light flashing in the dispatch room. At the same time, an audible tone warns the dispatcher to direct the foreman by public address system to the machine requiring assistance. Once the foreman diagnoses the trouble, he plugs his portable telephone handset into the control box to ask the dispatcher to send a repair man or a new supply of stock.

If much time is needed for repair, the foreman may then transfer the operator from a productive rate to downtime status by inserting key into the control box to cause the red lamps at the machine and in the dispatch room to burn steadily. This tells the dispatcher that a machine is inoperative and the worker on downtime status. The foreman then assigns the operator to another machine.

Each display panel on the control cabinet carries four electromechanical registers. These devices show productive time, downtime, number of parts produced within the shift, and the balance of the unfinished order. As long as the green light is on, the productive register shows the time elapsed. The "parts" register is actuated by pulses from a limit switch or photocell on the machine and counts the pieces produced, while the balance register subtracts an equal number of parts. Whenever a foreman turns his key and the red light goes on, the productive time register stops and the downtime counter is started. As soon as a balance register reaches the total of parts to be made, the green light begins to flash and a buzzer warns the dispatcher that the order is complete.

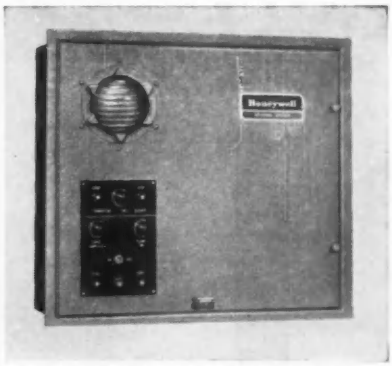
At the end of each shift or run, dispatchers transfer all production statistics to a five-channel tape that is used by such company departments, as accounting, planning, purchasing, production, and engineering to instantly compute their requirements and the day's production data.

With 200 machines connected to a Telecontrol, cost per machine is about $250. As an indication of the economies possible, the Hancock installation permitted the transfer of 16 foremen to other tasks.

—John D. Cooney

PRESSURE CONTROLLERS for high or low-limit cutoff or signalling, or for control of pressure and vacuum in many ranges from 0 to 1000 psi.

REMOTE BULB TEMPERATURE CONTROLLERS for high or low-limit cutoff . . . signalling . . . and automatic on-off, two-position, floating or proportional control with electrically or pneumatically operated valves, dampers, refrigeration units and similar equipment.



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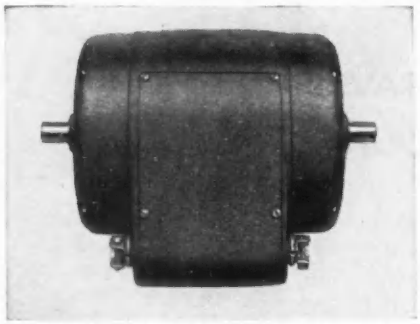
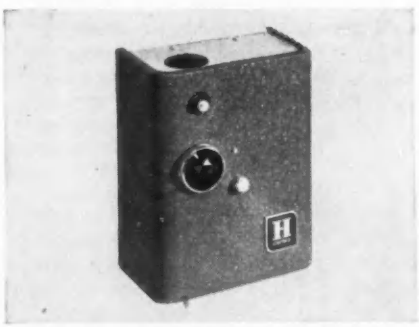
Add low-cost automation ...with Honeywell industrial controls



INDUSTRIAL MOTORS for electrical operation of valves, dampers and auxiliary switches.



ALARM SILENCING RELAYS permit an alarm to be silenced, and light an integral red light until an unsafe condition has been corrected. Relay automatically resets the alarm when safe conditions are restored.

You don't have to spend a lot of money for dependable automatic controls. Like many manufacturers, you can use various Honeywell industrial controls as the efficient, low-cost means of automating your equipment . . . improving performance . . . increasing safety. And, you can use these inexpensive controls to save time, money and space by extending automation in your plant or process.

There are more than 9000 standard types of Honeywell controls to handle temperature, pressure, liquid level and humidity—for control, switching or safety functions. There are electric, electronic and pneumatic types.

Though they're low in cost, these controls are top-quality, reliable devices. If there's not already a standard control for your particular application, Honeywell can design and build one for you.

Your nearby Honeywell field engineer will be glad to discuss your control requirements. Call him today . . . he's as near as your phone.

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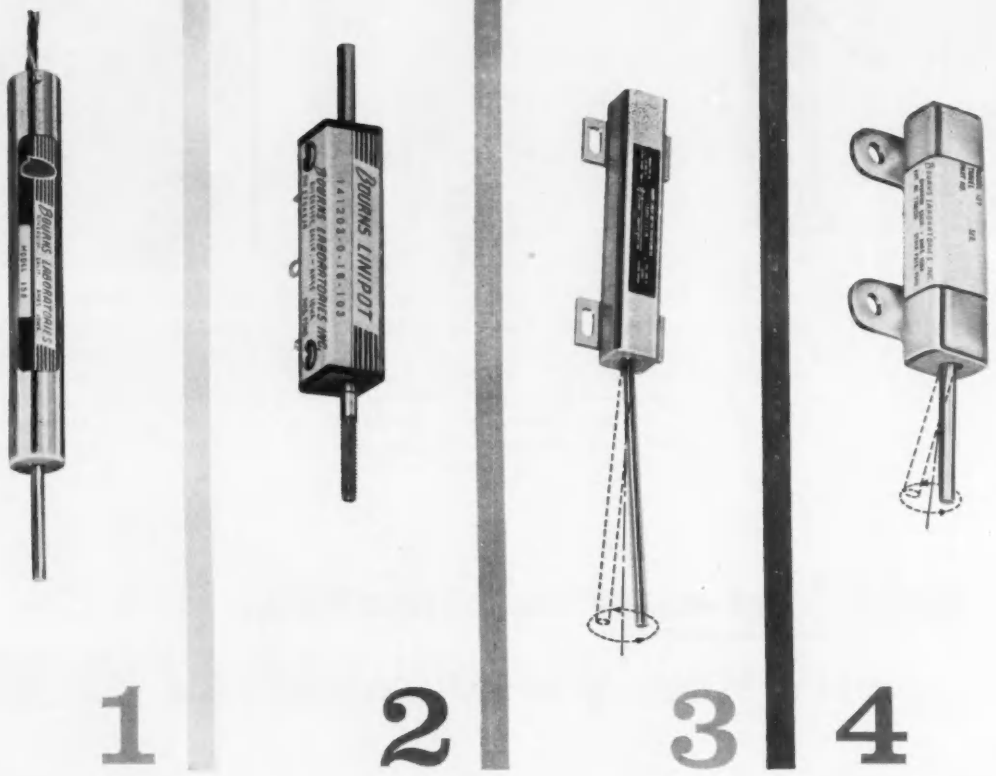

FOUR IMPORTANT NEW SHORT-TRAVEL POSITION TRANSDUCERS FROM BOURNS

Here are four problem-solvers made especially for travels of ½" to 6".
These are *small* instruments—units you can fit into the really *tight* spaces.
All of them offer long life under extreme vibration and heat *(as high as 450°F)*
...and each one solves a *special problem, too:*

1 FITS INSIDE ACTUATORS The Model 158 is small, tubular, unique—it fits *completely inside* hydraulic actuators or other telescoping devices.

2 FITS IN TIGHT SPACES The model 141 LINIPOT® is the smallest unit of its type available. Cross section is only ¼" x 5/16"

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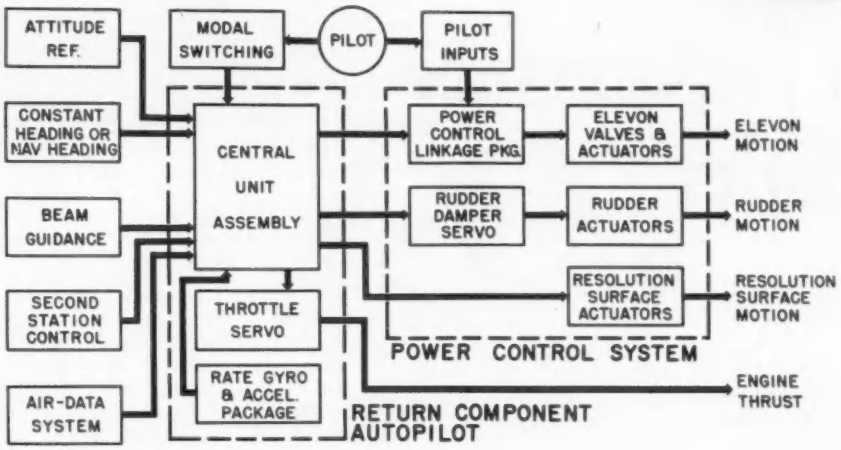


Block diagram shows how electronic, electro-hydraulic and hydraulic equipment goes together in flight control system of the B-58 Hustler. System senses and computes aerodynamic, effects on flight, then applies appropriate control action through power system.

B-58 Flexes Hydraulic Muscles

The impact of supersonic flight on aircraft flight control systems was demonstrated in March when Eclipse-Pioneer Div. of Bendix Aviation took the wraps off the "sophisticated" computer system that controls the Convair B-58 Hustler. Major characteristics: beefed-up hydraulic controls to deliver the tremendous forces required to move control surfaces of an airplane moving at speeds close to Mach 2; an electronic analog computer to calculate optimum action over a broad range of operating conditions.

Flight requirements of the Hustler posed a flock of new problems. It flies in three ranges of speed: subsonic, transonic, and supersonic, at speeds that vary from landing at 175 mph to a top speed of about Mach 2 (at 50,000 ft); and it flies at a variety of altitudes. In designing to effect the same maneuvers at various speeds and altitudes, engineers found that control surface movement was far from constant. Because the Hustler uses a delta wing configuration, it has only three control surfaces—two elevons and a vertical tail surface—instead of the five found in subsonic craft. And since the pod, carried slung under the ship, may be dropped in flight, the plane can change its aerodynamic configuration.

The Hustler's flight control system resembles other military aircraft control in that there are three main parts: sensing, computation and actuation.

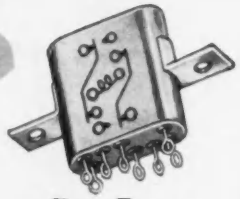
Sensing is accomplished by a central air data computer located in the needle-like nose of the bomber. It takes data on the plane's environment —air speed, temperature, air density— and converts it to numbers usable in the electronic "amplifier computer".

Computation and actuation take place through a third unit, called the Power Control Linkage Assembly (PCLA). This, say Bendix engineers, is the unique part of the control. PCLA is a complex electromechanical linkage that incorporates an analog computer and hydraulic valving (usually found spread throughout the plane) on a single platform that weighs 267 lb. It has over 17,000 parts.

In the PCLA, the pilot's control-stick movements are translated into just the right degree of control surface action by the power control part of the system. PCLA supplies the pilot with artificial feel so that he can sense movement of the stick and pedals in proportion to the degrees of surface motion required for the particular maneuver.

There's a ratio changing feature built into PCLA, too. It permits three different gain schedules, i.e., changes the amount of movement of the control surface at subsonic, transonic, or supersonic speeds. In flight, control surface movement for a specific maneuver may vary from a 20-deg movement under one set of conditions (low speed) to only 0.8-deg under opposite conditions. Yet the pilot feels no difference in the controls at the two extremes.

Bendix has also built in a "g"-limit-



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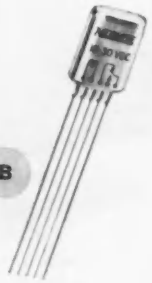

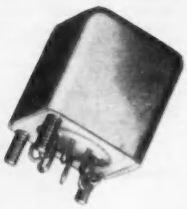

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Vibration: 10 to 34 cycles per second at maximum excursions of .4". 34 to 2000 CPS 20G's acceleration.
Weight: 0.45 ounce (max.)
Size: .875" high x .797" wide x .359" thick max.
Pull-in Power: 250 milliwatts at 25°C.
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Vibration: 10 G to 500 cps.
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Vibration: Low Frequency—10 G's, 10-55 CPS (total max. excursion, .06").
High Frequency—15 G's, 55-2,000 CPS.
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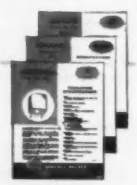

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WHAT'S NEW

Technicians adjust PCLA unit, 267-lb platform that centralizes all hydraulic valving in the Hustler's flight control system. It's main job: to translate electronic signals from the computer into linear motion.

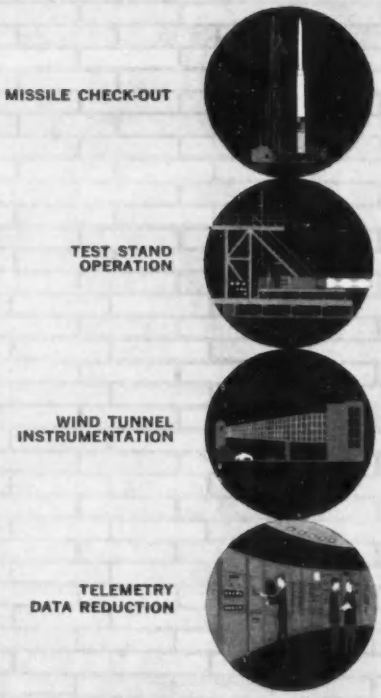
ing control. Infinite adjustment ratio changers vary stick motion and surface control available as a function of Mach number and ambient air density. This keeps the pilot from attempting a maneuver at high speed that might tear the ship apart.

Another problem that the control system must solve is "mixing". Because both banking and climbing are performed by movement of the same control surfaces—the elevons—the computer must decide the proper amount of movement and direction of each surface to accomplish the desired maneuver. There's also a built-in elevon-rudder interconnect. PCLA provides varying amounts of rudder surface motion for elevon stick inputs. This offsets rudder movement caused by air turbulence set up by movement of the elevons.

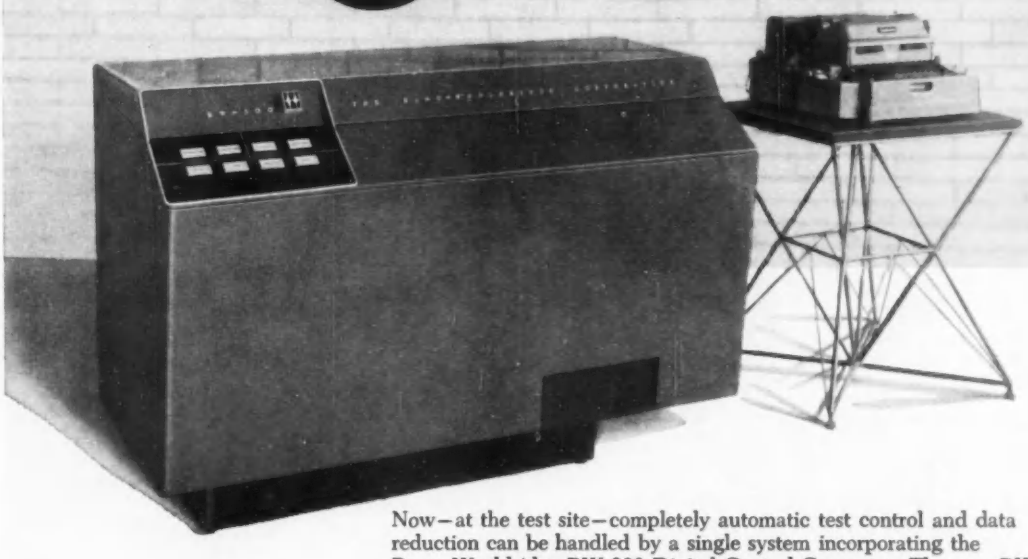
One other function that the PCLA unit accomplishes is stability augmentation, a damping of oscillations. Electrical signals derived from the autopilot computers actuate the electrohydraulic autopilot servomechanisms to control aircraft motion continually.

In pointing out how different the new control system is from conventional aircraft controls, Bendix engineers said that the surface actuators in the Convair 880 transport (CtE, Aug. '57, p. 22) exert a torque of 50 ft-lb, while those in the Hustler can exert a torque of 240,000 ft-lb.

Costs of developing the Hustler flight control system have run about $40 million. Currently under negotiation is a production contract that will total another $25 million.

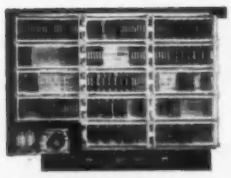


The RW-300 is the first digital computer for test control and data reduction



Now—at the test site—completely automatic test control and data reduction can be handled by a single system incorporating the Ramo-Wooldridge RW-300 Digital Control Computer. The new RW-300 can schedule and closely control test routines, and it can collect, analyze, and record test data.

The versatile RW-300 utilizes input data as feedback to modify control actions, thus substantially shortening many test routines. In addition, the RW-300 directly logs both instrument data and complex relationships among these data. Thus, test results are available immediately. The time-consuming task of processing raw data through a separate computer, often remote from the test facility, usually can be eliminated.



For technical information on automatic test control and data reduction with the RW-300 and with special digital systems which utilize solid-state components exclusively, write: Director of Marketing, The Thompson-Ramo-Wooldridge Products Company, P.O. Box 45607, Airport Station, Los Angeles 45, California, or call OSborne 5-4601.

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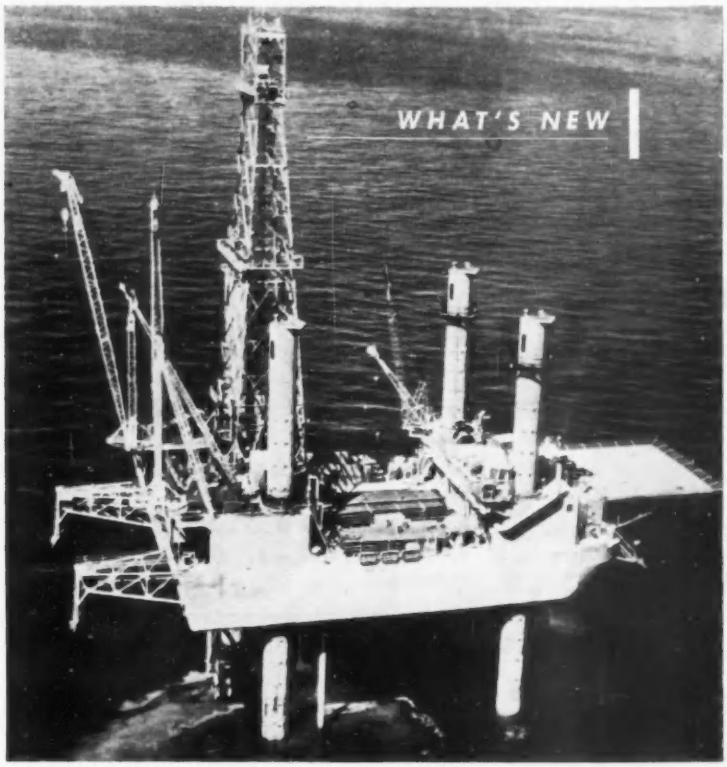

Automatic and semiautomatic electrohydraulic servos position world's largest drilling barge, solve the stability problem.

Mr. Gus' Position Controls

Mr. Gus II, a giant 9,000-ton oil drilling barge (photo above), introduced a new problem to oilmen. On land, stability of the drilling platform is no problem; but on the sea it assumes major significance. The owner, the C. G. Glasscock Drilling Co., solved the problem by first, lowering a giant steel mat to the ocean floor, and then jacking the 6,000 ton steel platform up out of the water. To do the job, Servocontrol Div. of the Oilgear Co. designed an automatic and semiautomatic electrohydraulic servo system.

Main components of the drilling barge are the mat, a platform, a drilling bridge, four caissons and the hydraulic jacking system. The steel mat is a 200 by 180 by 10 ft flat rectangular structure which serves as a foundation for the barge above when the mat rests on the ocean floor. Near each of the four corners are 10-ft-diameter cylindrical caissons extending upward 235 ft through openings in the platform. When the mat is lowered, these caissons serve as legs.

Around each caisson is an electrohydraulic jacking gear which lowers or raises the platform uniformly. This gear consists of six 20 in. diameter double-acting cylinders arranged in a circle around the caisson. Each ram end is bolted to a circular yoke on the caisson. The yoke carries eight locking pins which are moved in and out radially by air cylinders to engage corresponding holes in the caisson.

• **By its bootstraps**—The mat is lowered by a series of jacking actions under the control of the jacking "gear" cylinders. At each caisson the operation: 1) extends the rams from the cylinders to full stroke; 2) engages the yoke pins with the caissons, 3) pumps hydraulic fluid to the ram end of the six cylinders, pulling down on the caisson for a stroke of 8 ft, 2 in. (the distance between pins); 4) engages the platform pins to the caisson (thus locking platform to caisson); 5) retracts the yoke pins, and 6) repeats the procedure.

The four hydraulic systems, one at each caisson, operate independently. But they are synchronized through an

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EXACTLY to BuOrd Spec

Mark 1 Mod 1 TACHOMETER GENERATOR *(Size 15)*

MUIRHEAD

Supply	115V	400c/s
Generated Voltage per 1000 rev/min		3·1V
Phase Shift at 3000 rev/min		5° lagging
Residual Voltage at 0 rev/min		
R.M.S. 0·013V : Fundamental		0·008V
Weight	7oz	200g

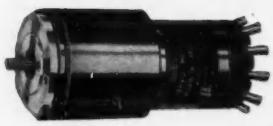
Mark 12 Mod 0 SERVOMOTOR *(Motor Tachometer Size 15)*

MUIRHEAD

Supply to Phase 1	115V 400c/s	
to Phase 2	115V 400c/s or 57·5V	400c/s
MOTOR PERFORMANCE		
Torque at Stall (minimum)	1·45oz in	104g cm
Torque at 2500 rev/min (maximum power output)	0·8oz in	58g cm
No Load Speed (minimum)		4500 rev/min
Weight with Generator	14oz	400g

The Generator figures are the same as for Mark 1 Mod 1 above

Mark 16 Mod 0 SERVOMOTOR *(Motor Tachometer Size 18/15)*



MUIRHEAD

Supply to Phase 1	115V 400c/s	
to Phase 2	115V 400c/s or 57·5V	400c/s
MOTOR PERFORMANCE		
Torque at Stall (minimum)	2·35oz in	170g cm
Torque at 2500 rev/min (maximum power output)	1·5oz in	110g cm
No load speed (minimum)		4500 rev/min
Weight with Generator	19oz	540g

The Generator figures are the same as for Mark 1 Mod 1 above

Servomotors can also be supplied with various low impedance control windings. Write stating your requirements.

Data sheets giving full information on the above and a handy reference sheet on our full range of Synchros and Servomotors are available on request.

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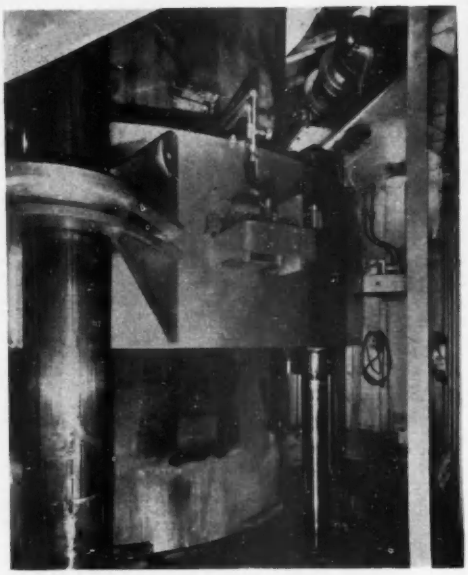

In interior of yoke room, caisson is surrounded by jacking mechanism. In jacking action, rams, bolted to yoke, are extended; yoke pins are then engaged.

electrohydraulic control mechanism which assures uniform movement and maintains close level accuracy. This control electrically compares and compensates for errors in the jacking speed of individual caissons.

As a safety measure, electric-operated hold-up valves (no power loss) are located as close to each cylinder as practicable to hold up the mass in case of power or piping failure.

• **The control loops**—The control console, from which all pumps are regulated, is located in a central control room on the main platform. A selector switch mounted on the console permits the operator to select any of the four modes of operation: central jacking, central windlass, individual jacking and pendant control. A spring-centered hand control sets the stroke or displacement of all pumps in unison (alternately supplying oil to the piston or the ram end of the jacking cylinders, depending on the direction of motion desired). It is also possible to operate each caisson individually, varying the amount of oil delivered to the cylinders to compensate for nonuniformity of load on the platform.

To avoid overloading the electric motors that drive the hydraulic pumps, a power limiting control decreases each pump stroke and volume of oil delivered when the horsepower de-

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EIA TO-9
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MEDIUM POWER AUDIO TYPES (To-9 Outline)											
2N381	Output Amplifier	200	25	25	200	85	20	36	1.2	31	2N61, 2N186/A, 2N187/A, 2N266
2N382	Output Amplifier	200	25	25	200	85	20	54	1.5	33	2N60, 2N180, 2N181, 2N185, 2N188/A, 2N226, 2N311, 2N403, 2N408
2N383	Output Amplifier	200	25	25	200	85	20	72	1.8	35	2N59, 2N224, 2N241/A, 2N265, 2N270
2N460	General Purpose Industrial	200	—	45	400	100	15	25	1.5	39	2N44
2N461	General Purpose Industrial	200	—	45	400	100	15	50	1.5	41	2N43
HIGH FREQUENCY TYPES (To-9 Outline)											
2N404	Computer	100	24	30	400	85	5	30	12	—	2N581
2N425	Computer	100	20	30	400	85	5	30	4	—	2N394, 2N578
2N426	Computer	100	18	25	400	85	5	40	6	—	2N269, 2N395, 2N579
2N427	Computer	100	15	20	400	85	5	55	11	—	2N123, 2N315, 2N396, 2N580
2N428	Computer	100	12	15	400	85	5	80	17	—	2N316, 2N397, 2N582
2N413	RF Amplifier	100	15	—	200	85	5	—	3	—	2N111, 2N135, 2N410
2N414	RF Amplifier	100	15	—	200	85	5	—	5	—	2N139, 2N112, 2N136, 2N218, 2N412
2N416	RF Amplifier	100	15	—	200	85	5	—	10	—	2N113
2N417	RF Amplifier	100	15	—	200	85	5	—	20	—	2N114
HIGH POWER TYPES (To-3 Outline)		Pc w	Vce volts	Vcb volts	Ic Amps.	Tj °C	MAX. Icbo ma	Hfe	fab mc	Ge db	
2N242	Audio Amplifier	15	45	—	2	85	1.0	50	0.4	34	2N155, 2N176, 2N250, 2N257, 2N301/A, 2N350, 2N351, 2N554, 2N555
2N378	Power Switch	15	20	40	3	85	0.5	35	0.3	24	2N255
2N379	Power Switch	15	40	80	3	85	0.5	30	0.3	23	2N158/A, 2N251, 2N296, 2N297
2N380	Power Switch	15	30	60	3	85	0.5	60	0.4	29	2N156, 2N256, 2N387
2N459	Power Switch	15	60	105	3	85	0.5	40	0.3	24	2N375

NOTE: *Similar type references are listed at time of printing and should be interpreted as approximate equivalents. This reference does not necessarily imply exact electrical or mechanical interchangeability.*

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This new AGASTAT time delay relay is an externally adjustable, double-pole, double-throw unit. It incorporates the basic AGASTAT timing principle, proved by a half-century of reliable operation on automatic aids to navigation, in a space-saving miniature unit, built to withstand the rugged environmental conditions of missile and aircraft applications.

For specific information on the new AGASTAT relay for your application, write to Dept. A29-520.

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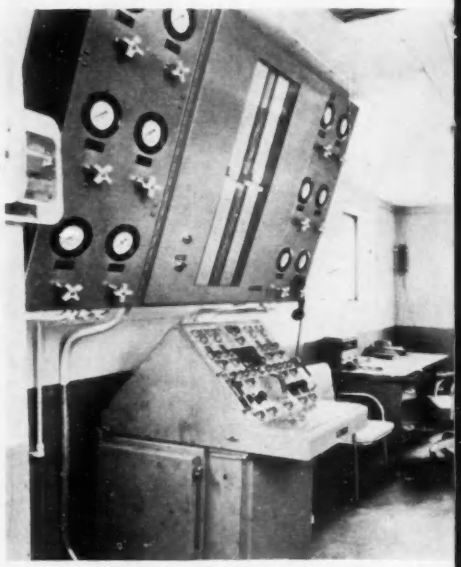


Compact console in main platform control room permits one man operation of the electrohydraulic jacking system. Here operator can select any of four modes of operation, can insure that jacking action proceeds uniformly.

mand exceeds a predetermined value. This action reduces jacking speed proportionately.

In the semiautomatic jacking system, the key component is an electrohydraulic stroker which varies the oil delivery rate and changes the direction of flow from the pump in response to a low-level electrical input signal. The command signal is relayed to a 1/150-hp servomotor geared to a hydraulic force amplifier which controls the position of the slideblock in the pump. Movement of the slideblock in the pump controls direction, and volume of oil flow—factors that control the direction, speed, or position of the piston within the cylinder. Feedback signals generated by potentiometers or synchros provide synchronous control of position velocity and/or acceleration.

• **Holding Mr. Gus down**—Once the mat is in place, the main platform is jacked up out of the water (in a manner similar to lowering the mat). While the platform is being raised, hydraulic pumps located halfway down the caissons drive 7 by 130 ft piles into the Gulf bottom. The piles act as locks to keep the barge from shifting or walking on the bottom.

Just how well this arrangement works was demonstrated last fall when Mr. Gus II withstood the violent blasts of hurricane Bertha.

TOP PRIORITY PREFERENCE

25 Traces on 7-inch Record

D/R DIRECT RECORDING DIRECT READOUT

MODEL 616 OSCILLOGRAPH

ACCURATE • TIME SAVING • VERSATILE

Twenty-five channels of direct recording are offered by this versatile Midwestern D/R 616 Oscillograph. Photographic records of the galvanometer traces appear rapidly on the seven-inch paper which requires no chemical development.

Advanced design of the D/R 616 permits the record to be ejected continuously for immediate handling, or for visual inspection plus automatic roll-up and storage of the record at the discretion of the operator.

Standard Midwestern Galvanometers are used.

If you have a problem involving data recording under normal or extreme conditions — one of the many specialized models of Midwestern Instruments' oscillographs will be your solution — Call, wire or write . . .

MIDWESTERN INSTRUMENTS 41ST AND SHERIDAN / TULSA, OKLAHOMA

Torque as low as 0.003 ounce inches achieved by Giannini in MICROTORQUE® and MINITORQUE® Precision Potentiometers

For extremely sensitive instrument applications where minimum torque is essential, specify Giannini Microtorque and Minitorque precision potentiometers. Highly reliable performance under the most rugged operating conditions is assured by Giannini's care for detail and production crafting.

By using sapphire jewel bearings... and precision ball bearings in certain Minitorque models, these 1 inch diameter instruments effect an unusually low coefficient of friction.

Available in 12 standard linear wiring types, the potentiometer output can, on special order, be designed to perform to a wide range of natural or empirical functions. All models employ non-corrosive precious metal windings and contacts... thereby permitting light brush pressures and ensuring long noise-free life.

Dependability, reliability, and ten years proven application success are your benefits, when you use Giannini Microtorque and Minitorque potentiometers—precision instruments "crafted with care."

For additional information, please write for Bulletins 85111 and 85151.

SPECIFICATIONS:

Torque	0.003 to 0.008 oz. in. depending on resistance and wiring type. (Sleeve bushing Minitorque 0.025 oz. in.)
Resistance Range	100 to 100,000 ohms.
Linearity	±0.5% (±0.25% on special order)
Power Rating	1.63 watts @ 25°C.
Shaft Diameter	Microtorque, 0.031 in., Minitorque, 0.125 in.

Giannini

G. M. GIANNINI & CO., INC., 918 EAST GREEN STREET, PASADENA, CALIFORNIA

WHAT'S NEW

Textile Companies Eye Computers for Production Control

ATLANTA—

Electronic computers have won their spurs with textile companies in accounting operations; all the major textile firms are using them for jobs that range from reporting sales performances to accounting record-keeping. But now textile executives are now setting their sights on an application that promises to solve one of their toughest problems: production control. Today the larger mills are making "feasibility surveys", and a few are making exploratory applications.

One mill has already launched an experiment that the industry is watching closely. It has tied loom pick counters to a central reporting area where graphs of loom operation are automatically and continually prepared. For every 200 picks on each loom, a symbol is produced on an electric typewriter (one typewriter can record for as many as 46 looms). The company is using the data to control down-time and yards produced.

This same company and its supplier are looking at still another step forward. They want to try recording the information on punched tape in such a way that it can be processed directly by the data processing system, and applied to a study of cost activity and work-in-process inventory. Such a conversion still presents some man-sized problems, but its potential value to both production and accounting departments is spurring research.

Development of special sensing elements is a major thorn. Said one application engineer, "Many of the special sensing elements to provide inputs and the special machines to use the output, to complete an overall optimum production system, must still be developed. As applications are proven and special input and output elements are developed, the trend will be toward completely integrated systems that incorporate measuring and sensing elements, data converters, special purpose computers and actuating equipment such as drives valves, solenoids, etc., to automatically achieve the optimum control of production."

At the present stage of development, the textile plants are using medium computer systems for the most part. Without exception, they're renting rather than buying, with

NEW! direct tank-mounted LIQUID LEVEL TRANSMITTER

Exclusive static pressure connection for closed vessels above or below atmosphere . . . eliminates need for second instrument.

This sensing diaphragm capsule flange-mounts directly on side of tank. All wetted parts of Type 316 stainless steel, with optional plastic coating for further corrosion protection.

with DIRECT 3-15 psi air output signal

IDEAL FOR: Viscous or corrosive fluids, slurries, and solids-in-suspension, as well as "easy-to-measure" fluids.

Now you can measure the level of "difficult" or easy-to-measure fluids — economically, without the complication of floats or bubble tubes, and with *sustained high accuracy over the entire range span.*

Flange-mounted directly to the side of an open or closed tank, the Type 13FA Transmitter eliminates piping and purging. Its stainless steel diaphragm capsule senses level changes instantly. Conventional tubing leads its output air signal directly to standard 3-15 psi receiver-recorders and controllers without need for intermediate signal converters.

The 13FA provides an accurate, trouble-free solution for level measurement problems. Write for detailed information, or ask your nearby Foxboro Field Engineer to explain its application to your specific process. **The Foxboro Company, 365 Norfolk St., Foxboro, Mass., U.S.A.**

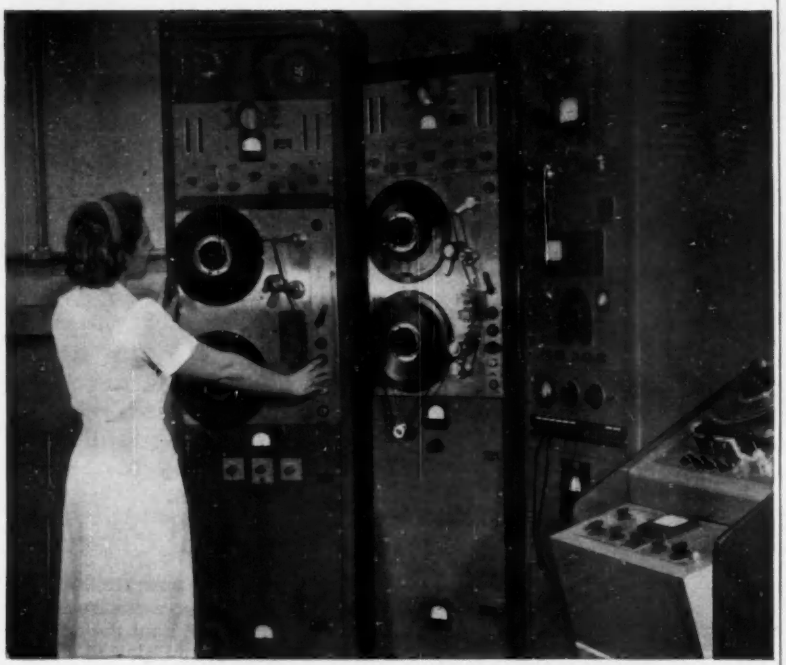
FOXBORO

REG. U.S. PAT. OFF.

LIQUID LEVEL TRANSMITTERS

The world's toughest referee

...a count of one and the tape is OUT!



The machine above is a unique testing instrument, designed by Audio Devices engineers and installed at the Audiotape plant in Glenbrook, Conn. This Automatic Defect Counter records and plays back every inch of the EP Audiotape under test.

Type EP is the extra precision magnetic recording tape for applications in computing, automation, telemetering and seismography. If the tape fails to record a single test pulse out of the millions put on a single reel, the entire reel is rejected. There are no ifs, ands or buts.

This is one of many special quality-control operations to which type EP Audiotape is subjected. The extra attention begins at the raw material stage where the master rolls of base materials are critically examined for uniformity of gauge, freedom from stretch, and cleanliness. The oxide and binder components are selected for fineness of dispersion and magnetic properties—then combined and fed through a micronic filter and metered on the seleeted foil in Audio's special dust-free precision coating machines. The coated master rolls are then selected for freedom from imperfections and proceed through the slitting operation. Each ribbon is wiped after slitting to remove all traces of dust, run through the defect counter, rejects discarded, and the defect-free tape packed in hermetically sealed metal cans or plastic cases.

The defect counter does its job so well that type EP Audiotape is *guaranteed* to be defect-free! For more information write for free Bulletin T112A. Write Dept. TC, Audio Devices, Inc., 444 Madison Avenue, New York 22, N. Y.

type EXTRA PRECISION EP audiotape TRADE MARK

AUDIO DEVICES, INC.,
444 Madison Ave., N. Y. 22, N. Y.

Export Dept.: 13 East 40th St., N. Y., 16 • Cables "ARLAB" • In Hollywood: 840 N. Fairfax Ave.
In Chicago: 5428 Milwaukee Ave. • Rectifier Division: 620 E. Dyer Rd., Santa Ana, Calif.

monthly rentals running from $10,000 to $20,000.

J. P. Stevens & Co.–a giant in textiles–now has a medium computer system, according to Robert T. Bruce, director, systems and procedures. The company is currently establishing five data processing centers to serve its 46 plants. Information from these points will be funneled into the major center at Charlotte, N. C., set up about two years ago. Artery of the system is a closed Teletype circuit. Bruce said that the transition from a high-type standard punched card system to a medium computer operation normally takes a textile company somewhere between 24 and 30 months.

When buying computer equipment, textile companies look for gear that fills a wide range of needs. Bruce cites one application at Stevens that requires 110,000 lines of printed information every week, another that requires only 2,000. And the rate of change in reflecting information demanded by the first application is relatively slow, but on the latter it's extremely high.

–Francis Ridgeway
Atlanta News Bureau

Simulation Conference Readies Program

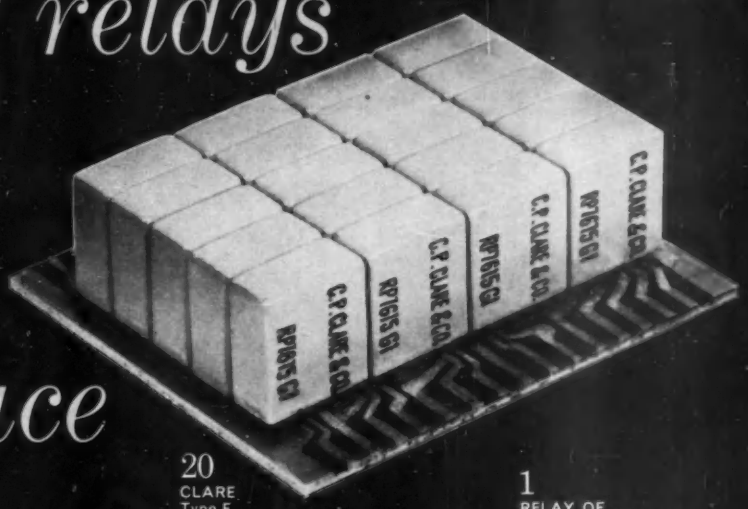
This year Dallas, Tex., will host the National Simulation Conference. Louis B. Wadel, acting chairman, has announced that the meeting will be held Oct. 23-25 at the Dallas Statler-Hilton Hotel.

The conference is sponsored by IRE's Professional Group on Electronic Computers and the Dallas Section. Last month it issued a call for technical papers covering, said Wadel, analog and/or digital simulation of mathematical, physical, logistic, economic, biological, or chemical systems; new advances in analog computer system and component design; new methods of determining and improving the accuracy of analog solutions; and new techniques and applications of simulation.

Aligning Guidance Systems

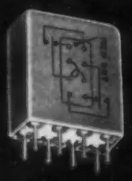
Inertial guidance systems of the THOR, Air Force's IRBM, will be accurately aligned by an electro-optical system using an azimuth theodolite. The optical instruments are in production at The Perkin-Elmer Corp., Norwalk, Conn.

20 times as many relays in 1/3 the space



20
CLARE
Type F
RELAYS
10¼ cu. in.

1
RELAY OF
EARLIER DESIGN
31¼ cu. in.



CLARE *Type* F RELAY

SPECIFICATIONS:

Ambient Temperature	—65° C to +125° C.
Shock	50 Gs for 11 milliseconds.
Vibration	5-75 cps at maximum excursion of ¼-inch, 75-2000 cps at 20 Gs acceleration.
Dielectric Strength	Sea level—1000 volts rms between terminals and frame, and between adjacent circuits; 750 volts rms between contacts of a set. At 80,000 ft., 350 volts rms.
Insulation Resistance	1000 megohms minimum at 125° C.
Coils	Coils up to 10,000 ohms available for a wide range of voltages or currents.
Nominal Operating Power	250 milliwatts.
Pickup Time	3.5 milliseconds nominal.
Dropout Time	1.5 milliseconds nominal.
Contact Arrangement	2 pdt (2 form C).
Contact Rating	3 amps resistive at 28 volts d-c or 115 volts a-c; also for low-level applications.
Contact Resistance	0.050 ohm maximum.
Contact Life	500,000 operations minimum at 2 amps; 100,000 operations minimum at 3 amps.
Enclosure	Hermetically sealed, filled with dry nitrogen at 1 atmosphere pressure.
Mounting	All popular mounting arrangements available.
Terminals	Printed circuit; solder; plug-in (matching socket available). Variations of printed-circuit terminal length on 1/10-inch grid spacing available.
Weight	17 grams.
Military Specifications	MIL-R-25018; MIL-R-5757C, except as to contact overload.

These twenty Clare Type F Modular Relays, mounted on a printed-circuit board, take less than a third of the space occupied by a hermetically sealed relay of earlier design—a relay in wide use a few short years ago.

Clare Type F Modular Relays can be mounted in a closely restricted space—wherever the user desires—on a board punched at 2/10 inch intervals in a grid pattern.

This new hermetically sealed relay—no bigger than a postage stamp—is fast and more than moderately sensitive, yet stalwart enough to withstand extremes of temperature, heavy shock, and severe vibration.

Send for Bulletin 124 today. Write: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., 2700 Jane Street, Toronto 15. Cable Address: CLARELAY.

CLARE RELAYS

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Changes in the British Scene

The announcement of a company name change—from Pantiya Tea & Rubber to Pantiya Electronics—typifies what's taking place in Britain's $900 million electronics-instrument industry. At present some 1,850 companies with a workforce topping 200,000 are in the electronics business. Seven hundred of these are very small—less than 50 employees each. Of them, about 250 produce only one or two items of highly specialized equipment that are unobtainable elsewhere in Britain. If you're in any way involved in electronics in Britain today, you're *getting in*, you're *growing*, or you're *getting out*.

• **In**—Statistics of new entries to the field are hard to come by, since the industry is still struggling for official recognition. Although many people consider it a young offshoot of the radio or electrical industry, pressure is building up to make it an entity.

Estimates of new firms vary from 30 to 75 a year. Some of these are the usual two-or-three-man teams formed to exploit an idea. But the majority are like Pantiya Tea & Rubber, which found the going tough on their Ceylon plantations after local nationalization threats, and looked around for a more profitable line. Electronics was the obvious answer, and their spare money bought up some of the small firms that had a good idea but not the money to exploit it.

People like Pantiya and Gas Purification & Chemical Co. are the angels for today's small new entries. Gas Purification & Chemical, founded in 1873, threw off their original aim of supplying material to the gas industry soon after the first World War, when it entered the machine tool business. Now the firm operates purely as an investment company controlling some 17 subsidiaries, with products ranging from relays and electrical switchgear to tape recorders.

• **Growing**—Here is the most spectacular change. Former specialist companies that started in the immediate post-war years are moving into wider fields. Take the Solartron Group. Its 1950 monthly sales in instruments totaled a mere $4,500. Now, with a finger in computers, industrial electronics and cybernetics, sales are up to $300,000 a month.

Signing licensing agreements with firms such as Rheem Mfg. Co. and Consolidated Electrodynamics Corp., Solartron has expanded internationally. Its latest arrangement, announced this month, puts it in the nuclear instrumentation and cold cathode tube field: marketing on a world-wide basis such products of the English Ericsson Telephone Co. as counters, scalers, and dekatron tubes.

Another British firm, R. B. Pullin, once just a meter manufacturer, today has six subsidiaries specializing in optics, meters and electromedical gear. As a result of their recent agreement with Kearfott, they have opened a new 70,000-sq-ft factory devoted entirely to the manufacture of synchros and gyroscopic components.

But of all these expansions, that of Elliott-Automation (see CtE, March '58, p. 48) has been the most marked. This is the one company in Britain that can provide every type of control and industrial equipment.

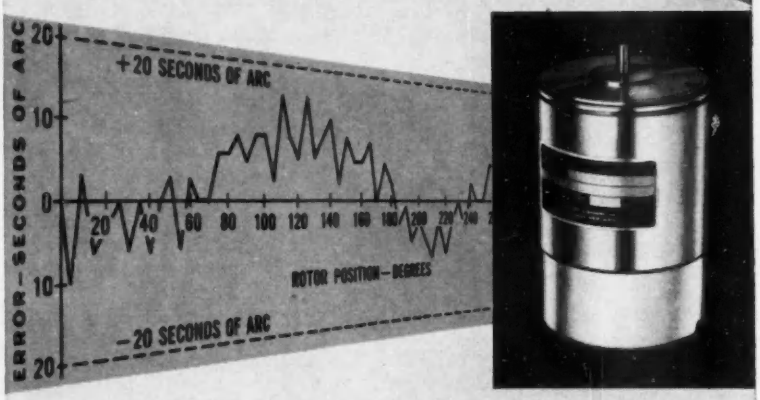
Other giants, like the Associated Electrical Industries group and English Electric, have had extensive reorganiaztions in the last few years. AEI has given a new look to its control and electronic activities, putting these on a par with its heavy engineering work, long its mainstay. Its subsidiaries, British Thomson-Houston and Metropolitan-Vickers, are putting more emphasis on computers, machine tool control, and industrial control.

Control is becoming more prevalent at English Electric, too, which is striving to commercialize its computer and guided weapons knowledge, and at Electrical Musical Industries and the Mullard-Philips group, both of which aim to get their share of this market: EMI with its computer, machine tool control, and tape controlled conveyor systems; Mullard-Philips with its solid state switching.

• **Out**—This is the unknown factor. How will the small firms survive under these changing conditions? In the past, they were helped along by Government contracts, especially in the atomic energy field where small quantities of highly specialized gear were needed (the large firms would not touch this type of work then). But now, with the construction of nuclear power stations becoming the responsibility of big private groups instead of the government-run United Kingdom Atomic Energy Authority, the big groups are taking over the manufac-

SYNCHRO ACCURACY **20** SECONDS OF ARC

ELIMINATE MULTI-SPEED SERVOS AND COMPLEX ELECTRONIC DEVICES



NEW ULTRA-PRECISE SIZE 25 SYNCHROS

Extremely precise data transmission is possible through the use of Kearfott's Size 25 synchro resolvers. The inherent precision of these units provides a three sigma accuracy of approximately 35 seconds in a typical 3 unit string without the use of auxiliary equipment. Ruggedly constructed of corrosion resistant materials, they possess the required reliability for all missile applications. Available as transmitters, differentials and control transformers with a maximum error from E.Z. of *20 seconds arc.*

SIZE 11 SYNCHROS

Size 11-2 phase 4 wire synchro resolvers for data transmission combine the advantages of small size with high accuracy. Corrosion resistant materials are used in the construction of these units. Available as 60X transmitters, differentials and control transformers with a maximum error from electrical zero of *3 minutes arc.* Standard 3 wire synchros are available from production with 5, 7 and 10 minute maximum error from E.Z.

ENGINEERS
Challenging opportunities at Kearfott in advanced component and system developments.

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ture of such instrumentation too.

The small firms at the crossroads are hamstrung because they can not afford the R&D cost to expand into wider fields. Of these 700 small firms, probably up to 300 will vanish in the next six to eight years. Where will they go? Some will become subsidiaries on which the giants can call for specialized knowledge and development. About a third will survive as separate entities for the simple reason that they will have forged for themselves a strong position in a field that is too narrow and specialized to attract the big firms. And the rest will probably disappear into the nether regions unless they meet a financial angel to guide them back to the starting line once more.

—Derek Barlow

Britain's Control Body Virtually Complete

The election of Dr. Galloway as chairman of Group A of the British Conference on Automation & Computation completed stage two in the formation of Britain's official automation and control body.

The idea of BCAC was first born in April 1957. Its function: to speed an exchange of information among the many specialized technical societies covering the control and automation field in Britain. Some 21 societies are associated with BCAC, which is split into three groups.

Group A, formally constituted in February, covers engineering applications of automation. A second group will cover problems of computation and automatic controls. It's chairman: T. E. Goldup, a director of the Mullard group and president of the Institution of Electrical Engineers. The two vice-chairmen are J. F. Coales of Cambridge University and E. M. Renals. This group came into being in December. The third group will emphasize the sociological and economic aspects of automation techniques; it has not yet been set up.

One of the first tangible signs of this intersociety cooperation will appear in the structure of the 1959 symposium on "Instrumentation and Computation in Process Development and Plant Design". The London symposium, held under the aegis of BCAC, is being planned jointly by the Society of Instrument Technology, the Institution of Chemical Engineers and the British Computer Society.

STANDARD INDUCTORS

★ HIGH DEGREE OF ASTATICISM TO EXTERNAL FIELDS

★ HIGH STABILITY OF INDUCTANCE ★ HIGH Q AT OPERATING FREQUENCY

★ SMALL INDUCTANCE VARIATION WITH CHANGES IN FREQUENCY and CURRENT

★ LOW TEMPERATURE COEFFICIENT

General Radio manufactures a variety of fixed and variable standard inductors in different price ranges. Fixed inductors are toroidally wound to minimize effects of external magnetic fields. Toroidal air-core inductors like the Type 1482 approach the ideal — they offer higher stability, lower temperature coefficient, and much smaller inductance variation with current changes than is produced by solenoid or iron-core inductor types.

Type 1482 Standard Inductor — a primary standard for precise measurements at audio frequencies. All units are thermally aged to equalize winding strains. Sixteen models from 100 μh to 10 h in 1-2-5 sequence. May be used for 2- or 3-terminal measurements. Temperature coefficient, 30 parts in 10^6 per degree C. Adjustment accuracy for most units is ±0.1%. Calibration certificates furnished with each inductor give actual value to ±0.03%. Prices range from $105 to $210.

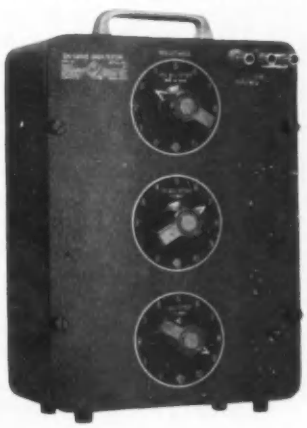
Type 107 Variable Inductor — two concentrically-mounted coils are used as rotor and stator, and may be connected in series or parallel. Calibration accuracy is ±1%. Five models available with following series-connected values: 9-50 μh, 90-500 μh, 0.9-5 mh, 9-50 mh, 90-500 mh. When parallel connected, inductance is one-fourth of series-connected value. Prices range from $85 to $95.

Greater economy in coil construction is obtained by using "iron" cores. By proper design and use of materials such as powdered molybdenum permalloy, excellent secondary standards can be produced and sold at relatively low cost.

Type 1481 Standard Inductor — has higher Q at low frequencies than does Type 1482 Standard Inductor, although accuracy is not as high. Twelve models are available, from 1 mh to 5 h in 1-2-5 sequence (for 2-terminal measurements only). Temperature coefficient of inductance is about 25 parts in 10^6 per degree C, between 16° and 32°C. Accuracy is ±0.25% for large values, ±1% for smaller values. Prices from $32.50 to $40.00.

NEW

Type 1490 Decade Inductor — is an assembly of three or four Type 940 Decade-Inductor Units in a metal cabinet for 2- or 3-terminal measurements.



NEW **Type 940 Decade-Inductor Unit** — an assembly of four toroids series connected by a rotary switch to produce eleven successive values from 0 to 10. These units are ideal elements for use in filters, equalizers, and tuned circuits throughout the audio and low r-f ranges.

Type	Inductance	Accuracy	Price
940-E	1 mh/step	±2%	$100
940-F	10 mh/step	±1%	100
940-G	100 mh/step	±0.5%	100
940-H	1 h/step	±0.25%	110

Type	Inductance	Price
1490-C	1.11 h max. in 1 mh steps	$330
1490-D	11.11 h max. in 1 mh steps	440

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DIEHL*
SERVOPOT

...solves your servo packaging problems!

The DIEHL SERVOPOT is an integral combination of a two-phase instrument servomotor, gear reduction, slip clutch, and precision potentiometer.

Conceived with the idea of offering precision servo performance in a modular construction, the SERVOPOT eliminates the present burden of mounting, testing and aligning separate units.

The SERVOPOT finds wide application in balancing, positioning and computing servos. Addition of an integrally-mounted DIEHL 0.5% A.C. tachometer makes the SERVOPOT *a complete integrating servo.*

The built-in slip clutch is factory adjusted to permit servo operation into potentiometer stops without damage. Standard pots featuring 0.5% linearity can be obtained in a wide range of resistances. Single, multi-turn, and non-linear models are available.

Diehl*

Consult DIEHL for further information, including integral mountings for resolvers and variacs.

DIEHL MANUFACTURING COMPANY
Electrical Division of THE SINGER MANUFACTURING COMPANY
Finderne Plant, SOMERVILLE, N. J.
Other available components:
A.C. SERVOMOTORS • A.C. SERVOMOTORS WITH A.C. TACHOMETERS
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D.C. SERVO SETS • RESOLVERS
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WHAT'S NEW

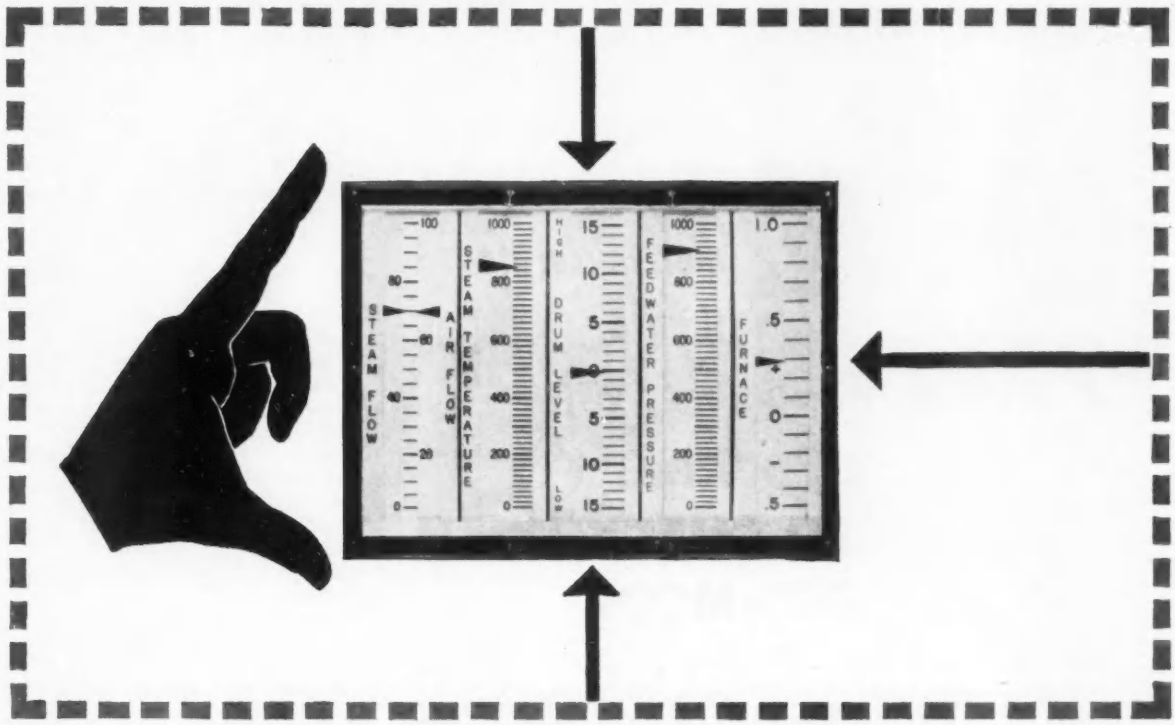
IRE Show: Emphasis on Components

To the control engineer, IRE's National Convention is rapidly becoming a components show: of the 850 exhibitors at the 1958 convention, 136 highlighted control components and only a handful stressed systems. Finding the 136 among the crowded aisles (total attendance exceeded 50,000) on the four floors of the New York Coliseum was simplified some by floor-by-floor sectioning into related product groups — equipment, components, instruments, and production. The third floor collected 43 of the 136 displays of interest.

As if to point up the emphasis on components, only 9 manufacturers showed or featured systems as such, and even computers were not much in evidence. The major analog computer manufacturers were present, and active. But only three digital machines were there, and one was the Litton 80 digital differential analyzer (a digital solver of analog-type problems), and another Ramo-Wooldridge's RW-300 process control computer. This left Royal McBee's LGP-30 general-purpose digital computer with the show to itself. Philco Corp., however, was showing its new TRANSAC S-1000 two blocks away at the Barbizon-Plaza. The S-1000 is a completely transistorized scientific computer with 4,096 36-bit words of core storage.

• **New semiconductor devices**—Of the components shown, two new semiconductor devices were interesting. One was a new field-effect varistor, developed at Bell Telephone Laboratories. This is a two-terminal element that maintains current constant within 1 percent over a voltage range from 20 to 120 volts. Current ratings from 10 microamps to 10 milliamps are possible. The second was Texas Instrument's "Sensistor", a silicon resistor said to be the first one available to produce a stable, retraceable increasing resistance with increasing temperature. The positive temperature coefficient is quite large—about 0.7 percent per deg C.

Clevite Research Center exhibited a demonstration model of a magnetographic recorder that combines some of the ease of use of direct-writing oscillographs with a frequency response better than available photographic-paper types. The new technique uses a special magnetic head to trace a 0.0015-in.-wide magnetized line on



Get big-gauge accuracy and sensitivity with

Republic's V5 Series of Compact Measuring Instruments

Two sets of Republic V5 gauges mounted on a modern console-type boiler control panel. Gauges match the compactness of the other instruments, yet are easy to read—even from a distance.

Republic V5 gauges feature full-sized diaphragms, bellows and helixes, yet require only one-fourth as much panel space as ordinary instruments. *Eight* V5 gauges can be mounted in a single bank requiring only about 14" x 6½". This compactness makes them ideal for console or graphic type panels. Each V5 gauge is an independent unit, which may be removed or replaced without disturbing adjacent gauges. Each 5" vertical scale is illuminated from the rear for top readability—even from a distance.

A full line of V5 gauges is available for measuring draft, pressure, differential gas pressure and temperature, and for use as receivers with pneumatic transmitters for indicating flow, liquid level, density, high pressures and other process variables. If you would like to save panel space—without sacrificing instrument readability, performance and flexibility—a talk with your Republic engineer could be time well-invested. A card or a call will bring him. Republic sales offices are located in principal cities throughout the United States and Canada. Detailed information in Bulletin No. 806 . . . your copy is waiting.

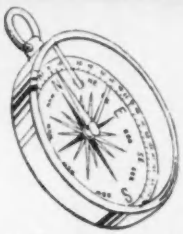
A FEW OF THE OPTIONS AVAILABLE:

- Duplex bellows or helix gauges with two pointers operating on the same scale; occupies same space in group as a single-gauge unit.
- Set point indicator available on single bellows and helix units.
- Compound and reversed scales available.
- Reverse acting pointer motion available. (Can be reversed in the field without any change in parts.)
- High and low alarm contacts can be provided with all types of units.

REPUBLIC
FLOW METERS CO.

Subsidiary of ROCKWELL MANUFACTURING COMPANY
2240 DIVERSEY PARKWAY CHICAGO 47, ILLINOIS
In Canada: Republic Flow Meters Canada, Ltd.—Toronto
Manufacturers of electronic and pneumatic instrument and control systems for utility, process and industrial applications.

When a pocket compass is more accurate than a G-2 Compass...

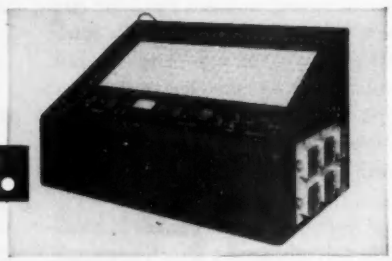


IT'S TIME TO CHECK WITH DIT-MCO!

Impossible for a G-2 to be less accurate than a pocket compass? Definitely not! The G-2 can fail because of high resistance leakage paths between terminals of the terminal strip. These are minor discrepancies which would not cause *complete* malfunction and, in all probability, would pass visual inspection or functional tests. However, the error is enough to cause compass inaccuracy now and complete malfunction in the future. This is just one of many potentially dangerous borderline faults which are virtually impossible for most circuit testers to detect. There are no wiring flaws in a pocket compass, but there are *countless* error *possibilities* in a G-2 . . . errors which *must* be found! That's why we say, "IT'S TIME TO CHECK WITH DIT-MCO"!

DIT-MCO Circuit Analyzers detect these finite and elusive wiring flaws every time! Unlike other circuit testers, DIT-MCO tests one wire against all other wires commoned together . . . *simultaneously* and *without special connections*. This is the only valid leakage test. Because of test accuracy, reliability and completeness, DIT-MCO Circuit Analyzers save time and money in all phases of production, modification and maintenance of aircraft, missiles, radar, computers . . . wherever highly complex, multiple interconnected circuitry must be tested.

Write today for important facts about DIT-MCO equipment and service. If your product requires accurate electrical tests, DIT-MCO can do the job faster . . . more efficiently . . . more economically!



DIT-MCO, INC.

Electronics Division, Box 05-32,
911 Broadway, Kansas City, Mo.

A Partial List of DIT-MCO Users:

Aircraft Radio Corp. ● AiResearch Manufacturing Co. ● American Bosch Arma Corp. ● American Machine & Foundry Co. ● American Motors ● Amphenol Electronics Corp. ● Autonetics, A Division of North American Aviation, Inc. ● Bell Aircraft Corp. ● Bendix Aviation Corp. ● Boeing Airplane Co. ● Cessna Aircraft Co. ● Chance Vought Aircraft, Inc. ● Chrysler Corp. ● Convair ● Douglas Aircraft Co., Inc. ● Dukane Corp. ● Electronic Products Corp. ● Fairchild Aircraft Division ● Farnsworth Electronics Co. ● Frankford Arsenal ● General Electric Co. ● General Mills, Inc., Mechanical Division ● General Precision Laboratory Inc. ● Goodyear Aircraft Corp. ● Grumman Aircraft Engineering Corp. ● Hazeltine Electronics Division, Hazeltine Corp. ● International Business Machines Corp. ● Lockheed Aircraft Corp., Missile Systems Division ● Martin, Baltimore ● Minneapolis-Honeywell, Aeronautical Division ● Motorola, Inc. ● Northrup Aircraft, Inc. ● Pacific Mercury Television Mfg. Corp. ● Radio Corp. of America ● Radioplane Co. ● Raytheon Manufacturing Co. ● Servomechanisms, Inc. ● Sikorsky Aircraft ● Sperry Gyroscope Co. ● Summers Gyroscope Co. ● Sun Electric Co. ● The Swartwout Co., Autronic Division ● Temco Aircraft Corp. ● Thompson Products ● Topp Industries Inc. ● Trans World Airlines ● U. S. Naval Air Station Overhaul and Repair Depots ● U. S. Naval Ordnance Laboratory, White Oak ● Vertol Aircraft Corp. ● Western Electric Co. ● Westinghouse Electric Corp.

WHAT'S NEW

. . . magnetic recording is developed immediately; tape can be washed, erased, used again . . .

1½-in. magnetic tape with a linearity of 1 to 2 percent for frequencies from dc to 10,000 cps. The magnetic recording is developed immediately in the demonstration recorder by passing the tape through a liquid suspension of black magnetic oxide which clings to the magnetized line. The tape can be washed, erased, and used again; fixed permanently; or copied by impression of the original against paraffin-coated paper tape. Five or so good copies can be made from the original in this manner. An important advantage is the relative economy when recording high frequencies, since the recording medium can be reused many times.

Among the systems exhibited, American Bosch Arma's inertial platform for the Air Force's Titan ICBM was calculated to stop control engineers. Arma has just signed a $140 million contract to provide pure inertial guidance systems for Titan.

• **Correlation spectroanalysis**—One of the most interesting systems shown at IRE, International Telephone & Telegraph Corp.'s, was developed for cancer research. It wedded a recording infrared spectrophotometer, a taped "library" of spectrographs of "pure compounds", and a digital correlation computer. In the method of analysis used presently, biological specimens from cancer patients or control donors are spectrographed, and the spectrographs compared with others selected from a library of possible constituents. This comparison is an intuitive curve-fitting process, done by technicians thoroughly familiar with the library of spectrographs. Since the specimen to be analyzed may have four or five or more major constituents, the curve fitting may take a day or two, and even then the error in fit may be 20 to 30 percent.

The new correlation computer searches the library for the constituents of the specimen in a few minutes, comparing 3,000 points in the infrared spectrum for each, and produces a qualitative (which constituents) and quantitative (how much of each) answer with an error of only about 4 percent in the curve fit. This final error can be due either to errors inherent in the library of spectrographs of the pure constituents, or to the existence in the specimen of small

AMM

ANTI MISSILE MISSILE

WHEN "MINUTES" COUNT

SYNCHRO FUNCTION	CPPC TYPE	PRIMARY Input Voltage (400~)	Input Current (Amps.)	Input Power (Watts)	Output Voltage (Volts)	Sensitivity (MV/deg.)	Phase Shift (deg. lead)	D.C. RESISTANCE Rotor (Ohms)	Stator (Ohms)	IMPEDANCE Zro (Ohms)	Zso (Ohms)	Zrss (Ohms)	Max. Null Voltage (MV)	ACCURACY Max. Error (Min.)
Torque Transmitter	CGC-8-A-7	26	.100	.5	11.8	206	8°	37	12	54 + j260	12 + j45	80 + j20	30	7
Control Transformer	CTC-8-A-1	11.8	.090	.2	23.5	410	9°	150	24	212 + j684	22 + j115	246 + j60	30	7
Control Transformer	CTC-8-A-4	11.8	.029	.08	22.5	390	8°	389	64	560 + j1860	90 + j340	640 + j190	30	7
Torque Receiver	CRC-8-A-1	26	.100	.5	11.8	206	8°	37	12	54 + j260	12 + j45	80 + j20	30	30 sp.
Electrical Resolver	CSC-8-A-1	26	.038	.42	10.8	190	20°	230	27	286 + j620	45 + j148	350 + j75	30	7
Electrical Resolver	CSC-8-A-4	26	.038	.42	26	454	20°	230	170	286 + j620	250 + j830	350 + j75	30	7
Control Differential	CDC-8-A-1	11.8	.085	.21	11.8	206	9°	36	25	38 + j122	27 + j120	48 + j14	30	7
Vector Resolver	CVC-8-A-1	26	.057	.34	11.8	206	10.2°	78	27	103 + j440	8 + j30		30	7

ACTUAL SIZE

Count on CPPC Synchros

In the above diagram, which simulates the attack of an ICBM and its destruction by an Anti-Missile Missile, only 20 minutes will elapse from the time advanced radar picks up the ICBM at point a and the time ICBM reaches its target. These are a vital 20 minutes.

In these 20 minutes the path of the ICBM must be computed with extreme accuracy and the intercepting path of the Anti-Missile Missile computed equally accurately.

Minutes count—both minutes of time and minutes of maximum error in the computing devices.

Clifton Precision synchros offer highest accuracies in standard synchro units. Special units are available which eliminate, for practical purposes, all synchro error. In addition, reliability standards are the most stringent we can devise and still mass produce synchros.

Delivery time has been shortened and production capacity approximately doubled with the opening of our Western Division at Colorado Springs, Colorado.

For full information, call or write Sales Department, Hilltop 9-1200 (Suburban Philadelphia) or our representatives.

LOOK TO CPPC FOR SYNCHRO PROGRESS

cppc

CLIFTON PRECISION PRODUCTS CO., INC. Clifton Heights, Pa.

S-D Type 180 Midget D-C Telephone Style RELAY

featuring a large number of contact arrangements in small size at minimum cost.

NEW RELIABILITY

for a popular multi-contact relay type

The big story about this popular midget relay type is not that it is new . . . but that Struthers-Dunn now makes it. Material and design improvements scored by S-D engineering spell maximum dependability and long life—yet at no price increase.

As illustrated, 16 flexing contact springs can be supplied with 8 springs in each of two stacks. Standard relays withstand ambient temperatures to 85°C. Special types for ambients of 125°C. are available. Minimum power requirements are on the order of 100 milliwatts per pole.

A-C VERSIONS for continuous duty can be supplied.

FOR MILITARY APPLICATIONS, SD Type 180 Relays are widely used for ground and aircraft electronic and communications equipment.

FOR COMMERCIAL USES. Type 180 relays provide maximum dependability for the numerous contact arrangements required for computers, instruments, signalling and annunciator systems and similar low power uses.

Data Bulletin No. 2180 request

Now! **STOCK DELIVERIES** from the factory on many of the S-D 5,348 relay types.

IMMEDIATE LOCAL DELIVERIES on many of the most popular types. Write for name of your nearest distributor.

STRUTHERS-DUNN, Inc.

Pitman, N. J.

Makers of the world's largest selection of relay types

Sales Engineering Offices in: Atlanta • Boston • Buffalo • Chicago • Cincinnati Cleveland • Dallas • Dayton • Detroit • Kansas City • Los Angeles • Montreal • New Orleans • New York • Pittsburgh • St. Louis • San Francisco • Seattle • Toronto

WHAT'S NEW

amounts of unknown, previously undectable compounds. Doctors at Sloan-Kettering Institute, with whom IT&T has been working, hope that this latter possibility may hold an important key to victory over cancer.

The idea of coupling a correlation computer with a recording spectrograph also offers new versatility to an old tool in the process industries. The analogous fields of ultraviolet and x-ray spectrometry, as well as gas chromatography, are open to study.

• **Technical sessions**—IRE's technical program as usual reflected the wide diversity of interests represented by its 28 professional groups. There were about an even dozen papers of prime interest to control engineers, but they were scattered throughout 55 technical sessions, some held concurrently at the widely separated Waldorf-Astoria and the Coliseum.

IRE's session on automatic control featured two papers on adaptive control and one on nonlinear circuits. The latter—Gain-Phase Relations of Nonlinear Circuits, by E. Levinson of Sperry Gyroscope Co.—was outstanding because the speaker presented a new concept for stabilizing systems with nonlinear circuits.

Levinson pointed out the need for nonlinear circuits exhibiting gain reduction—with increasing frequency—without phase change. It also described three general classes of such circuits, and an application of one of them to an actual servo.

The three classes of gain-reduction-without-phase-change circuits are high-pass – limiter – low-pass circuit, non-linear inductance and derivative circuit, and frequency controlled variable gain amplifier. The output response of these circuits is that of the fundamental (describing frequency) to each steady-state frequency existing by itself and generally with a particular magnitude. However, by constructing a circuit that minimizes the input magnitude effect, the desired "describing" characteristic can be obtained.

In the mock-up servo experiment, the improved stability obtained with the circuit verified the results expected from theoretical considerations. On this basis, Nyquist's stability criterion can be extended to systems employing nonlinear gain-reduction-without-phase-shift stabilizing circuits.

In a panel discussion on "Educational Needs in Systems Engineering", the speakers agreed that systems education meant breaking down the barriers between conventional fields of engineering. —E. J. Kompass

1092 CORE BUFFER

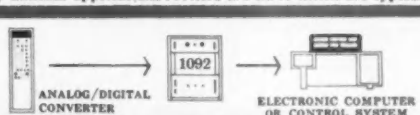
FOR BETTER BALANCED DATA HANDLING Two data systems of different operating characteristics can bog down your processing time, run up costs. Solution: make them compatible by using Telemeter Magnetics' 1092 Core Buffer, a completely transistorized buffer storage unit that synchronizes the major elements of differing digital systems. TMI, a pioneer in the development and manufacture of magnetic core storage buffers, has designed the Series 1092 to accept up to 1,092 eight bit characters and introduce them into storage with instant availability for output in the sequence previously loaded. Minimum loading or unloading time is 10 microseconds per character. Components are mounted on printed circuit plug-in cards. Contact a TMI representative, a specialist in the technology of magnetic core storage... by writing for complete details. Dept. CE5

0/1 TELEMETER MAGNETICS *Inc.*

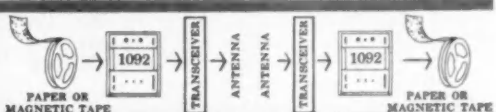
2245 PONTIUS, LOS ANGELES, CALIFORNIA

1092 Core Buffers can be put to work in many unusual applications... here are three which are typical:

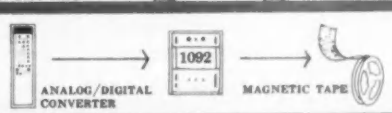
ON-LINE DATA REDUCTION: Digitized test data are stored in the buffer until called for by the computer. On command, data move instantly into the computer memory.



DATA TRANSMISSION Data are temporarily stored in the buffer at receiving and transmitting terminals to provide suitable speed synchronization between the link and data handling equipment.



RECORDING OF CONTINUOUS TEST DATA: Test readings are digitized and stored in the buffer so that a complete data block may be recorded on magnetic tape in the desired computer format.



Job opportunities available for design engineers, applications engineers, and physicists.

Post Decitron
electronic products

Model MC

Post's Multi-Channel Input unit . . . accumulates "counts" from several different production lines where total count is desired, utilizes separate photoheads for each line. Anti-coincidence circuit keeps count accurate even if objects on two different lines break beam simultaneously.

Model SD-IT

Outmodes all mechanical counters. Capable of operating at speeds up to 100 units per second. Single "count" indicated on the six digit totalizer as each *tenth* item breaks the light beam. Counts dozens or gross with 12 place counting tube.

Model PW-5

Preset electronic counter with built in warning system. Available in models for counts of 1-100 (PW-2) to model with range 1-100,000 (PW-5). Will count in batches. Warning device may be used to coordinate secondary circuit just before desired count is reached. Will stop machine, cut, divert or perform any other operation. Automatically resets to zero when preset number is reached.

POST ELECTRONICS

Division of Post Machinery Co.
160 Elliott St., Beverly, Mass.

Decitron

POST ELECTRONICS
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160 Elliott St., Beverly, Mass.

☐ Send literature on Model_____
☐ Please send name of nearest representative

Name_____
Company_____
Address_____
City_____ State_____

AROUND THE BUSINESS LOOP

Control and Recession

A look at the business picture as it affects the control field shows a lot of unevenness; but most observers feel that the hump is behind us.

In many ways the current economic recession is one of the strangest in the history of this country. There are the familiar signs of not much money and a lot of unemployment, but—and this is especially noticeable in areas where recession impinges on the engineering professions—these signs are not in clear focus. That is to say, in these areas there is and there is not a lot of unemployment, and there is and there is not a dearth of available funds.

Just recently, for instance, Consolidated Electrodynamics let 500 workers go, to mark the first major layoff in this company's history; also just recently, Hughes Aircraft announced plans to hire 3,500 technical and professional people. Almost coincidentally with these moves, Thompson Products reduced its manpower "in line with the declining volume of business" and RCA oiled up its idle recruiting machinery. How these and other control engineering companies did financially last year is shown in the table on the next page. What they said about what they did, and what they anticipate doing, is the subject of the box below.

But contradictory employment reports go only so far in showing the peculiarity of this recession, and in fact, can be explained, at least in part, by the government's erratic contracting procedures; though even here there is the element of deceptiveness.

New York Times economists call defense orders the most difficult item of the recession to evaluate. "Much of the increase," they say, "is merely to make up for the slow rate of ordering last summer, when the government was making an effort at an economy drive."

• **Less costs more**—One McGraw-Hill

WHAT THEY TOLD THE STOCKHOLDERS

AMERICAN BRAKE SHOE CO.: "Although sales and earnings records were established in the year 1957, the prospects for 1958 are not encouraging . . . we forecast lower shipments and earnings until such time as industrial production again moves upward . . . "

BORG-WARNER CORP.: "While we regret that sales, earnings and employment of most industries throughout the United States, including Borg-Warner, are being adversely affected in the economic readjustment now taking place, we are confident that . . . "

CLEVITE CORP.: "Extensive defense cutbacks and stretchouts during the year had a strongly adverse effect on our electronic equipment business, and our instruments business, which depends indirectly on defense contracts for a major part of its sales, declined."

CONSOLIDATED ELECTRODYNAMICS CORP.: "Consolidated was forced to act quickly after mid-year to reappraise its rate of growth and accordingly to adjust its operations to meet reduced 1957 sales goals . . . your company proved, under trying conditions, its ability to respond effectively to unexpected downward adjustments in the business cycle."

INTERNATIONAL RESISTANCE CO.: "IRC management has taken drastic measures to meet this recession. In November production was cut to prevent inventory build-up of components for consumer products. Early in January 1958, expenses were reduced by approximately 10 percent and are now effective."

THOMPSON PRODUCTS, INC.: "After rising to record levels . . . sales and earnings felt the impact of the unexpected drop in defense schedules . . . a swift change in our outlook . . . we moved promptly and aggressively to meet the situation."

All-in-one selector switch—indicating light by Westinghouse.

A start button, a stop button, an indicating light—all in one handsome, compact selector unit.

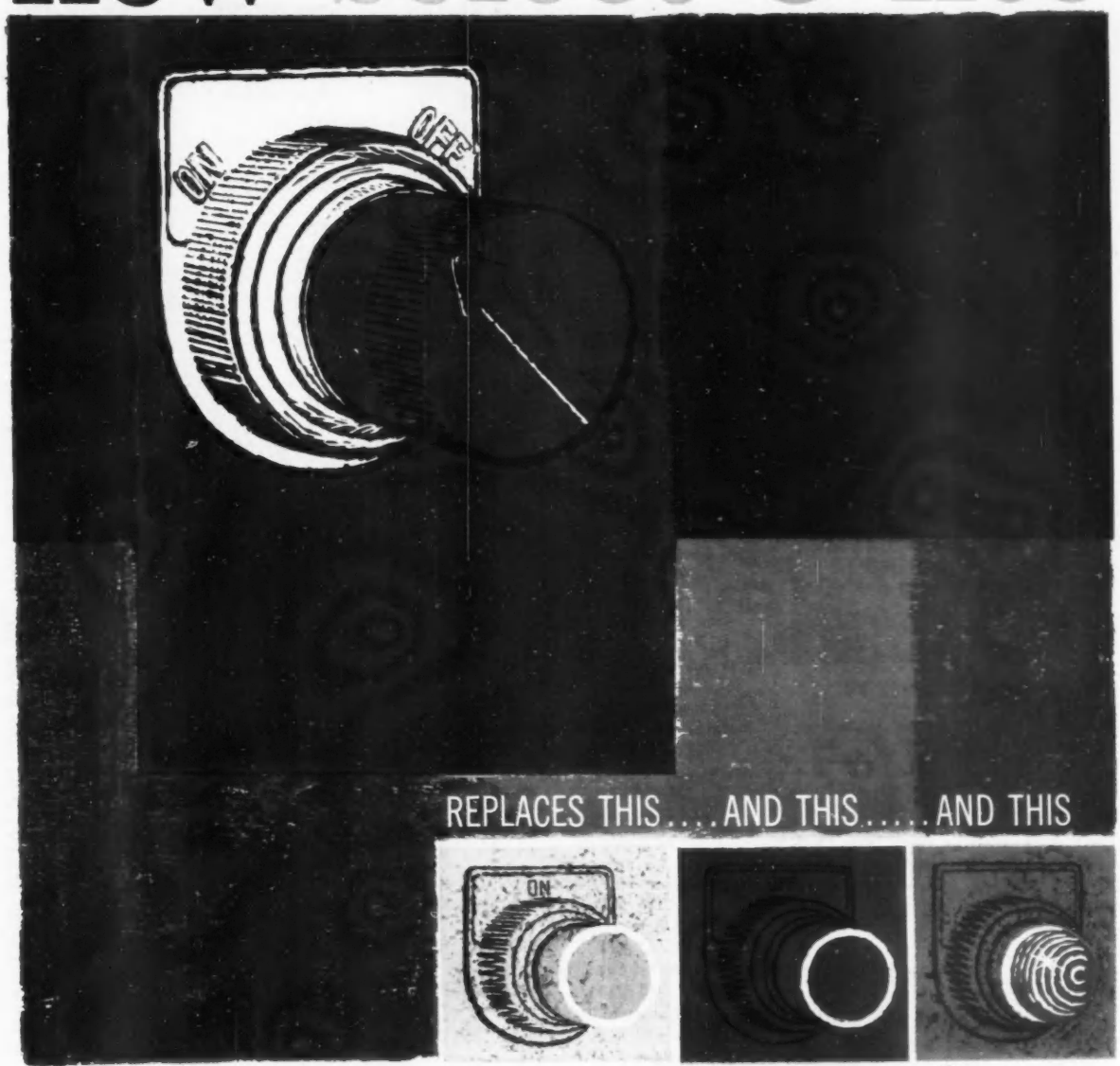
Saves up to 60% on panel space!

Saves considerable initial expense!

They're oil-tight, of course—with a panel-enhancing chrome finish—a lifetime operation snap-acting switch—and interchangeable nameplates for on-off, start-stop, forward-reverse. Or any combination you choose.

You can get full information, and a supply of Westinghouse selector-switches, by contacting your Westinghouse sales office or distributor. Or write the Westinghouse address shown below.

new select-O-lite



J-30296

YOU CAN BE SURE...IF IT'S **Westinghouse**

Westinghouse Electric Corporation
STANDARD CONTROL DIVISION
Beaver, Pennsylvania

HOW BORG EQUIPMENT DIVISION CAN HELP YOU

Our business is helping to solve design and production problems in the use of components for the highly specialized electronics industry. Borg's background provides the experience necessary to design and produce various types of components for you . . .

MICROPOT* POTENTIOMETERS

Borg Micropots offer a wide range of high-precision, single-turn, multi-turn and trimming potentiometers.

**Registered trademark of The George W. Borg Corporation.*

MICRODIALS

Direct Reading Microdials and Concentric Scale Microdials.

INSTRUMENT MOTORS

Rugged, dependable Borg-Motors are designed for quality instrument applications.

AIRCRAFT INSTRUMENTS

Instruments for commercial and military aircraft.

FREQUENCY STANDARDS

To meet your requirements in Frequency Standards for military or industrial applications.

TEST EQUIPMENT FOR AUTOMATION

Invaluable experience with automatic testing equipment is yours when you call on Borg.

Save time and money when faced with design or production problems of electronic components. Call on Borg. Let us send you the name of your nearest Borg "Tech-Rep" and a copy of catalog BED-A90 today.

OTHER BORG DIVISIONS

The George W. Borg Corporation is comprised of three divisions . . . the Borg Equipment Division at Janesville, Wisconsin, the Borg Fabrics Division at Delavan, Wisconsin which manufactures the fashionable "Borgana" fabric for coats and jackets and the Borg Products Division at Delavan, Wisconsin, leading manufacturer of automotive clocks.

BORG EQUIPMENT DIVISION
THE GEORGE W. BORG CORPORATION
JANESVILLE, WISCONSIN

WHAT'S NEW

HOW THEY DID IN 1957*

net income, 1957	net income, 1956	sales, 1957	sales, 1956
American Bosch Arma Corp.			
$5,080,387	$3,383,568	$134,339,863	$122,237,735
American Brake Shoe Co.			
$9,124,438	$8,963,359	$186,851,369	$186,142,261
American Machine & Foundry Co.			
$11,436,000	$8,621,000	$261,754,000	lower
Amphenol Electronics Corp.			
$1,686,594	$1,257,987	$31,410,903	$27,318,319
Atlantic Research Corp.			
		$2,400,000	$1,600,000
Borg-Warner Corp.			
$34,076,578	$35,841,952	$608,514,099	$598,695,774
Burroughs Corp.			
$10,074,594	$14,197,021	$282,773,950	$272,879,246
Clevite Corp.			
$7,408,539	$7,671,593	$72,672,288	$75,111,784
Consolidated Electrodynamics Corp.			
$771,729	$1,283,263	$30,541,382	$25,036,689
Dorsett Laboratories, Inc.			
		$225,000 (an increase of more than 50 percent)	
E. I. du Pont de Nemours & Co., Inc.			
$397,000,000	$383,000,000	$1,965,000,000 (an increase of 4 percent)	
Electronic Associates, Inc.			
$1,001,998	$929,811	$12,298,274	$8,816,952
Electronics Corp. of America			
$182,653	$476,467 (loss)	$8,037,554	$6,973,306
Fairchild Camera & Instrument Corp.			
$799,093	$910,324	$36,989,284	$42,969,036
Fisher Governor Co.			
$3,310,013	$2,608,899	$31,555,510	$26,657,897
General Precision Equipment Corp.			
$4,263,949	$2,394,729	$185,093,842	$153,261,864
International Resistance Co.			
$469,870	$523,416	$15,374,721	$16,787,913
Lear, Inc.			
$858,921	$1,506,018	$64,692,576	$63,900,786
Magnetics, Inc.			
$89,060	$85,988	$4,038,927	$3,001,301
Minneapolis-Honeywell Regulator Co.			
$21,350,000	$22,463,657	$324,800,000	$287,944,462
Motorola, Inc.			
$7,824,431	$7,966,817	$226,361,000	$227,562,000
National Research Corp.			
$209,211	$849,393	$8,739,365 (gross), up by more than $1,600,000	
Phillips Electronics, Inc.			
$376,819	$1,152,374 (loss)	$8,072,512	$2,671,376
Texas Instruments, Inc.			
$3,765,362	$2,349,103	$67,338,574	$45,699,358
Thompson Products, Inc.			
$11,942,034	$13,012,605	$368,578,428	$326,399,987
Tung-Sol Electric, Inc.			
$3,129,916	$2,909,397	$64,106,913	$53,838,822
Westinghouse Air Brake Co.			
$12,087,670	$11,924,073	$236,977,411	$214,652,560
Westinghouse Electric Co.			
$72,652,000	$3,492,000	$2,009,043,000	$1,525,375,000

* For additional annual reports, see CtE, Dec. '57, p. 52, and CtE, Feb. '58, p. 170.

source[2] points out that the standard of living has gone higher and higher, with less and less labor, but productivity, at least for the last two years, has declined. These economists do say, however, that if the annual rate of increase of productivity stays at its present 2.5 percent, this will be enough to send the gross national product from 1957's $434 billion to $581 billion in 1965 and to $835 billion in 1975 (all at 1957 prices).

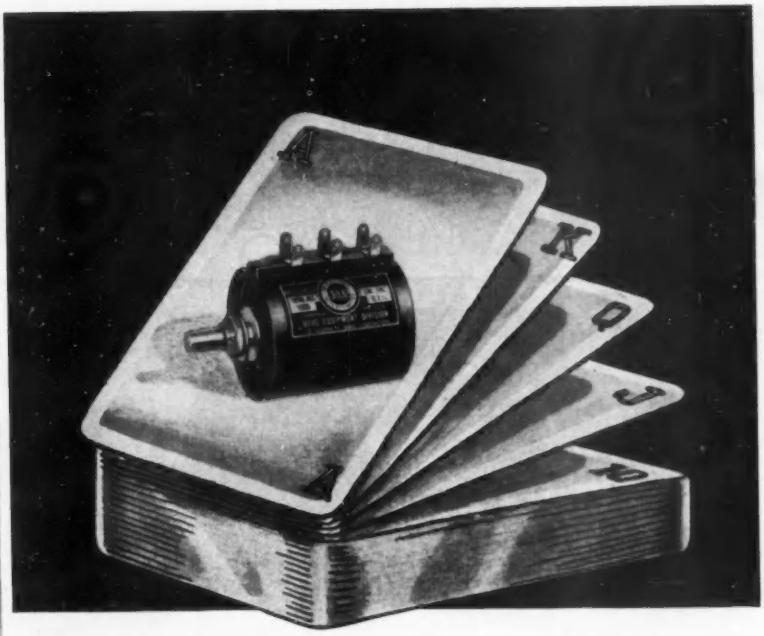
Another way to appreciate the unusual quality of this recession is to look at what is happening to some of the most important new engineering products. Take, for example, machine tools and transistors. The engineer in the machine-tool industry is finding his field "facing its severest decline since the great depression of 1929-1932" (Value Line Investment Survey), while the engineer who works with transistors is finding he's walked into a wide-open business.

Here are some figures on transistors, compiled by Electronic Industries Association: 2,955,247 units, valued at $6,704,383, sold in January 1958 (a possible record), compared to 1,436,000 units, valued at $4,119,000, sold in January 1957. Supporting these are figures furnished by the management staff of General Electric's transistor plant in Buffalo, N. Y.: 27 million units produced in 1957 and 48 million anticipated by the end of this year; and, transistor makers can expect a 360-400 million bonanza by 1965.

• **$40 million loss**—In January 1957, say the Value Line economists, orders for machine tools totaled $60 million, but by the time December came, these orders had fallen below $20 million. Backlogs are said to be declining fast, and no recovery of demand is in sight. One reason is "the virtual cessation of buying on the part of automobile and aircraft companies," which is explained in this way: "The automakers, plagued by sharply reduced demand and substantial excess capacity, have pared their purchases of tools and will probably remain out of the market, except for normal replacement needs, for several years to come. And because missile development is rendering manned aircraft obsolescent, demand for aircraft tools will probably never be great again, in the absence of an all-out war. A heavy demand for tools for military purposes is not likely until missiles reach the mass production stage—still some time away."

A somewhat brighter view (McGraw-Hill's) is that new orders for machinery (all but electrical) have already "bottomed out" and are on their way

[Continued on page 172]



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1. Lug-type terminals or coded flexible leads 9″ long.
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Built by Borg

MOTORS
MICROPOTS
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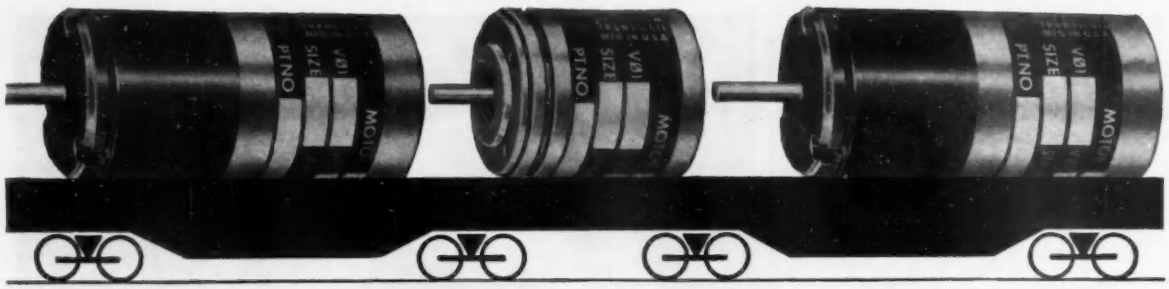

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You can now get Daystrom Transicoil quality *with 24-hour service.* Under our new stock program, Servo Motors and Motor Generators in all the popular ratings will be shipped within 24 hours of receipt of your order at the plant.

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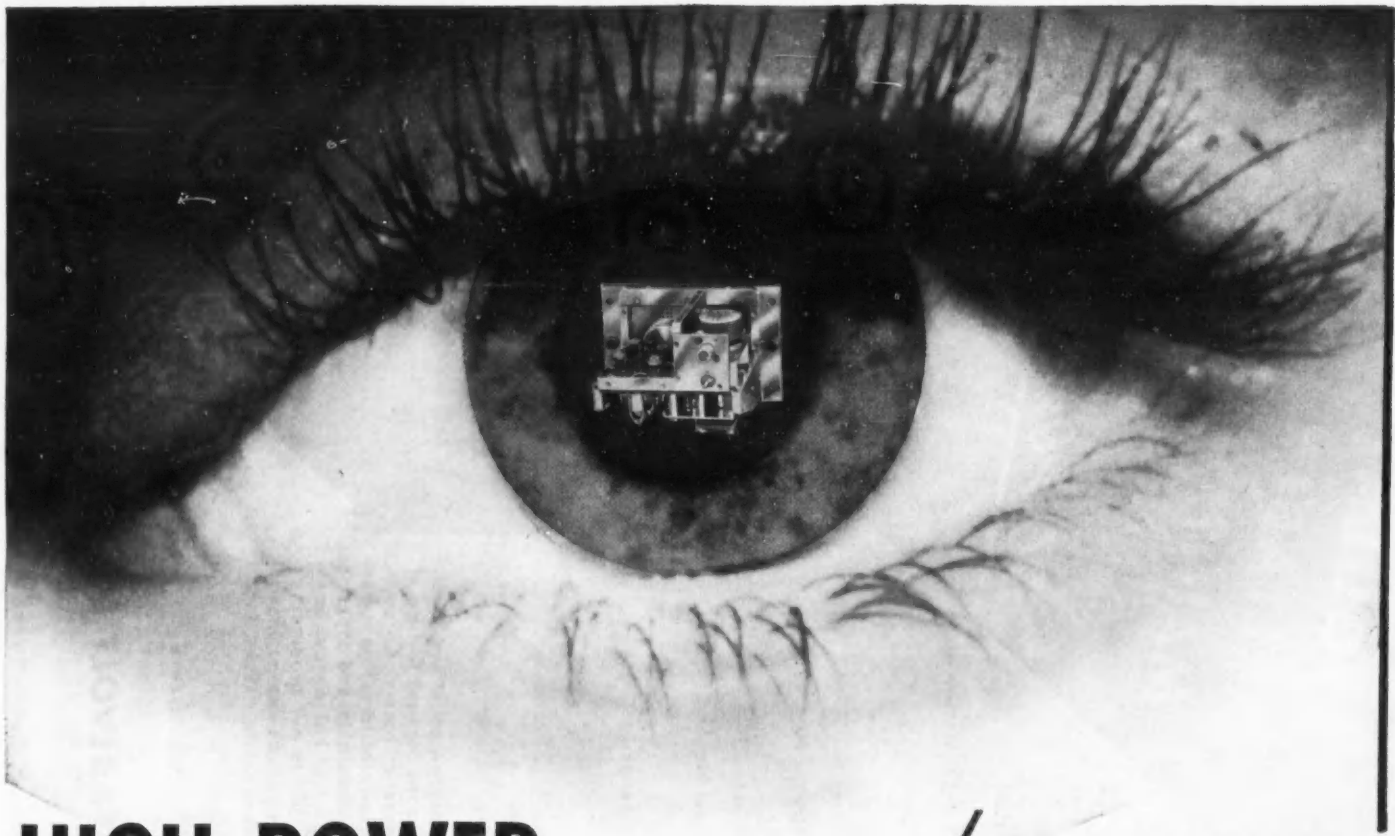

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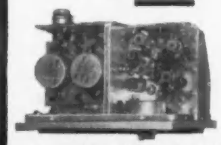
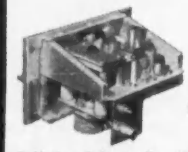


Model 1462

6" x 4¼" x 3¾" 50 to 80 Watts

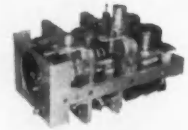


Model 1463

5'1/32" x 3'3/16" x 4" 15 to 30 Watts

Model 1472

4" x 1.5" x 2.7" 2 Watts



Model 1466A
6.5" x 4" x 3.25" RF Amplifier
2 watts in — 100 watts out

SUB-CARRIER OSCILLATOR.

Model 800C — 1.5" x 1.9" x 2.45"
Deviation stability ±1% of band width. Deviation linearity less than 1% of band width under all conditions measured from a straight line drawn between end points.

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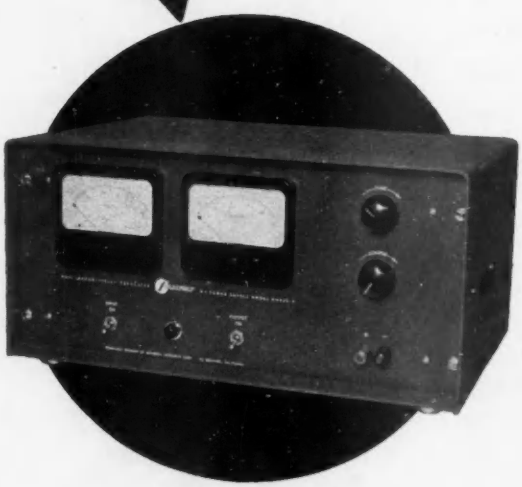

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Other Models Available

Write for Technical Bulletin DMR-100

These new power supply units from the Stablvolt Division of Magnetic Research Corporation carry the same high quality of workmanship and superior design that has always been attributed to our products . . . products you can depend upon to be the finest of their kind.

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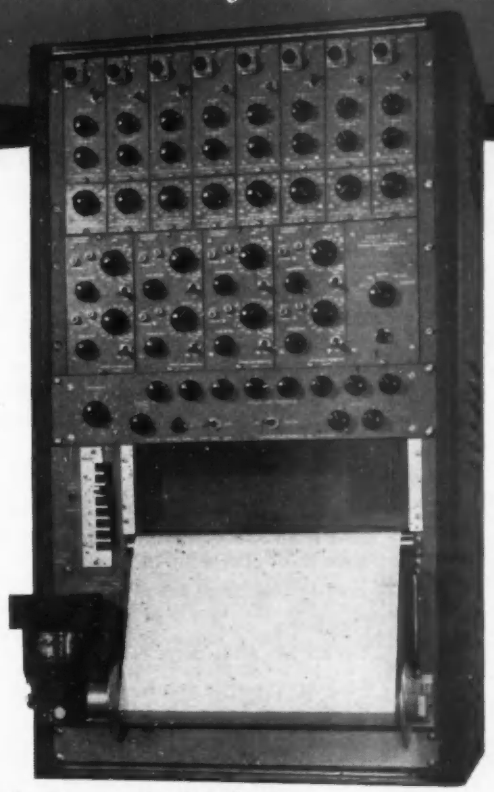
OFFNER ALL TRANSISTOR TYPE R DYNOGRAPH

the most versatile...most sensitive direct writing unit available

Combining all these features...



- ☆ **stable d-c sensitivity of one microvolt per mm**
- ☆ **true differential input**
- ☆ **high input impedance**
- ☆ **response to beyond 150 cps.**
- ☆ **reluctance, differential transformer, strain gage with a-c or d-c excitation, thermocouples, etc., used with all amplifiers**
- ☆ **deflection time less than 2 milliseconds**
- ☆ **fixed precision calibration**
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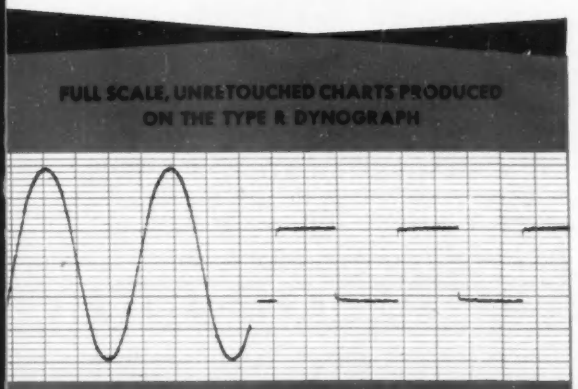
- ☆ **precision source for d-c and 400 cycle excitation, self-contained**
- ☆ **zero suppression, twenty times full scale, both directions**

all these features...plus 8 channels in only 33¼" of rack space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EXTREME SENSITIVITY—
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Four recording media. Heat or electric rectilinear —ink or electric curvilinear. Readily convertible.

Whatever your application for direct writing recorders . . . you should investigate the ability of the Offner Type R Dynograph to do the job *better* and more *simply*. Using transistor circuits* developed and tested for over two years in hundreds of channels of Offner medical equipment, the Type R Dynograph is, we believe, superior in practically every respect to *any other* direct writing oscillograph. Write on your company letterhead for literature giving details and specifications.

*Patents granted and pending

OFFNER ELECTRONICS INC.

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This is the
Honeywell 3170
precision tape transport

a rack-mounted unit designed by the largest manufacturer of instruments and controls —to meet the most demanding requirements of analog magnetic tape instrumentation.

Examine these brief specifications on the Honeywell 3170 high-performance tape transport—designed to provide unparalleled flexibility and performance in accordance with IRIG specifications. Complete mechanical and electronic data are available on request—including application engineering assistance.

Performance

Extremely low "wow and flutter."

Tape speeds available from 60 to 1½ ips . . . selected by switch, without belt changes.

Less than 2 seconds start time and 1 second stop time at 60 ips, with 14″ reels.

Fast forward and rewind.

Flexibility

Up to 14″ reels with NARTB hubs standard.

Plug-in, interchangeable, record and playback heads.

In-field changeover for tape widths of ¼″ to 2″.

Search and control capstan, optional.

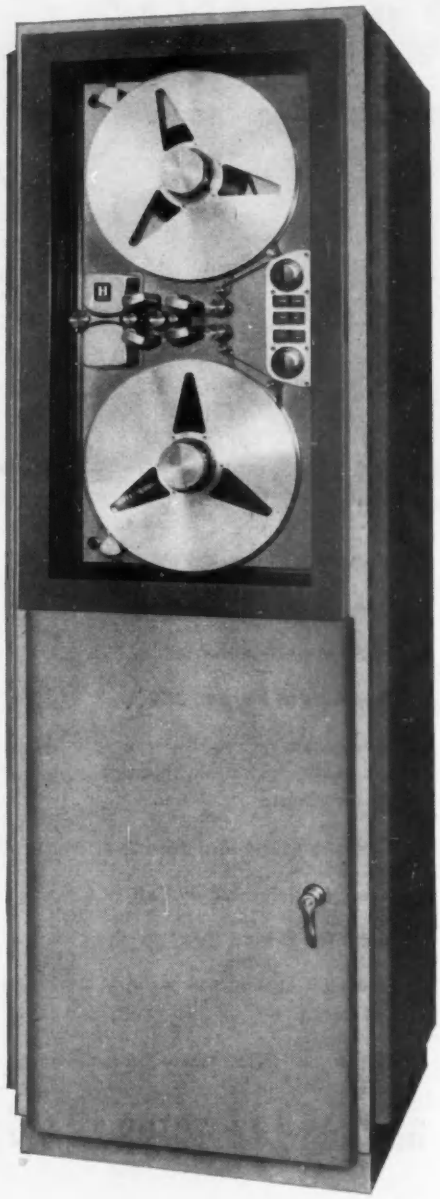
Features

Precision-ground mounting plates assure perpendicular head mounting on change of head stacks.

Precision capstan drive assembly with multiple-speed hysteresis synchronous motor, operated from line, speed control servo, or precision-frequency power generator.

Closed-loop isolation of tape path, with precision, non-mechanical tape tension control of both supply and take-up reels.

Honeywell multi-track heads—record and playback—conform with IRIG specifications.



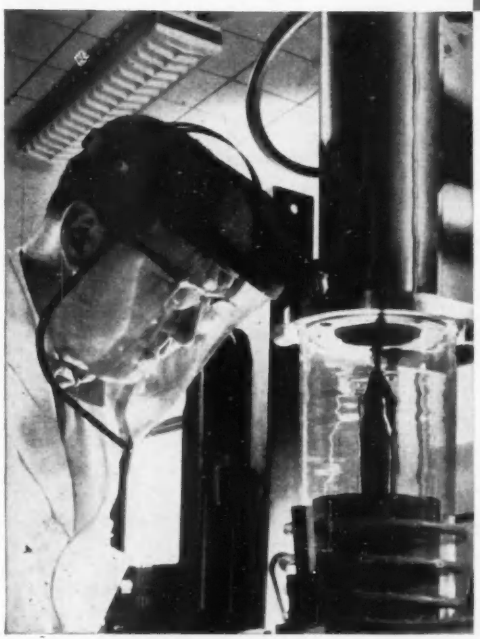
The complete Honeywell data acquisition system features direct, wide-band FM, multiplexed FM, or PDM data recording by means of plug-in amplifiers. Electronic components have low zero and gain drift with temperature and voltage changes. Signal-to-noise ratio exceeds IRIG specifications.

For detailed information, call your local Honeywell field engineer . . . he's as near as your phone. MINNEAPOLIS-HONEYWELL, 10721 Hanna Street, Beltsville, Maryland.

Honeywell

First in Controls

DELCO HIGH POWER TRANSISTORS are made from



In the center of the quartz housing, a germanium crystal is being grown. A "perfect crystal lattice," it will be cut into wafers 3/10ths of an inch square and less than 1/100th of an inch thick to become the heart of Delco High Power transistors.

GERMANIUM

because it alone combines these 5 advantages:

Lower saturation resistance—Germanium gives Delco High Power transistors a typical saturation resistance of only *3/100ths* of an ohm. No other present material offers this characteristic, which permits efficient high-power switching and amplification from a 12- or 24-volt power supply.

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Lower distortion—In many applications, distortion requirements can be satisfied only with germanium transistors.

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Greater economy—More power per dollar.

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Examine Delco High Power germanium transistors and see how practical it is to go ahead with your plans now. For high current applications there is no better material than germanium, or Delco Radio would be using it. All Delco High Power transistors are produced in volume; all are normalized to retain their fine performance and uniformity regardless of age. Write for engineering data and/or application assistance.

TIMERS...SPECIAL DELIVERY

Standard or special— Industrial Timer makes rapid deliveries on all models

Sometimes you need a standard model timer . . . other times you need a special. Either way we can give you the extra rapid service you may need because of the efficient way we design, manufacture and stock timers for industrial applications.

To meet *all* of the widely varying needs of our customers we manufacture a complete line of timers in the four broad classifications illustrated here:

1. **TIME DELAY TIMERS**
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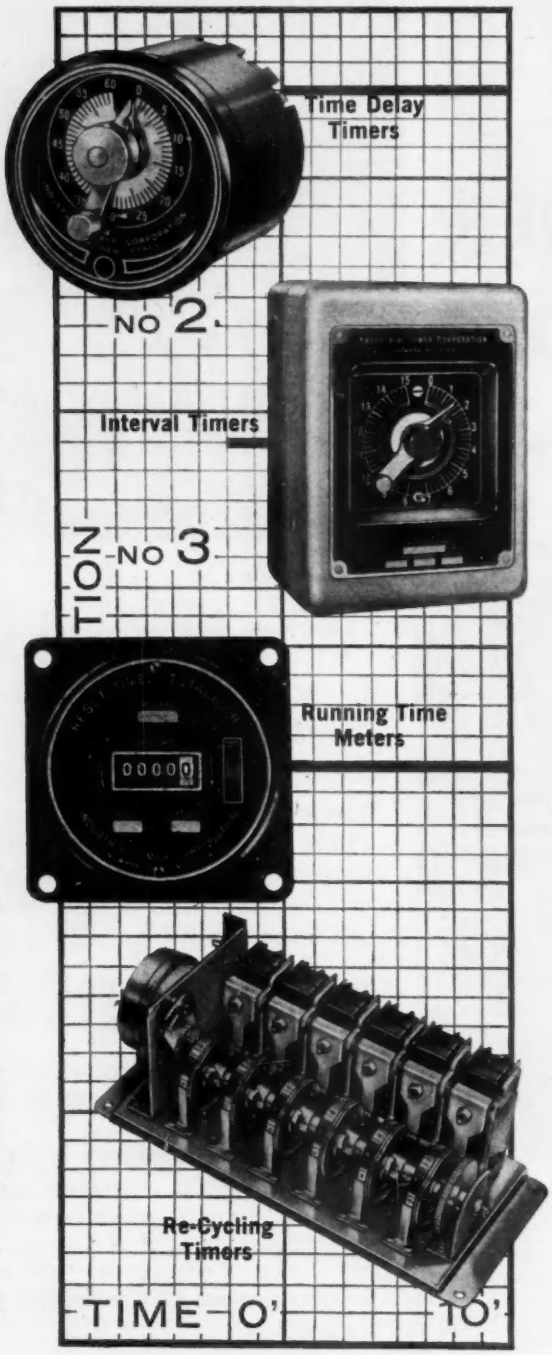
From these we have already developed 20 basic types which can be combined in endless number of ways . . . to date, our engineers have combined them into over 1000 different models. So what might seem to be a special timer requirement to you, will very often be a standard timer in our large stock, and that is the reason we have the ability to fill special orders so quickly. And as far as standard timers are concerned we can give overnight service if necessary.

So, for the utmost in all-round service depend on us for this outstanding combination: deliveries "Immediate on Standards . . . First on Specials".



Speed up your automatic control projects— profit by our timing application experience

No need to let timing problems delay you in your automatic control projects when you can place them with us and get faster solutions. Even though no two automatic control jobs are ever exactly alike, and even though the timer requirements of each are very different we have established an excellent record in helping out in these situations.

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Extra special automatic control timer — this calls for original designing. Our engineers will go right to work and get the job done. That's the way we grow and we like it.

Whatever your control problem, you have everything to gain by submitting it to our timer specialists. They'll come up with the answer — almost with the speed of automatic control itself.

AFFILIATE—LINE ELECTRIC COMPANY

Timers that Control the Pulse Beat of Industry

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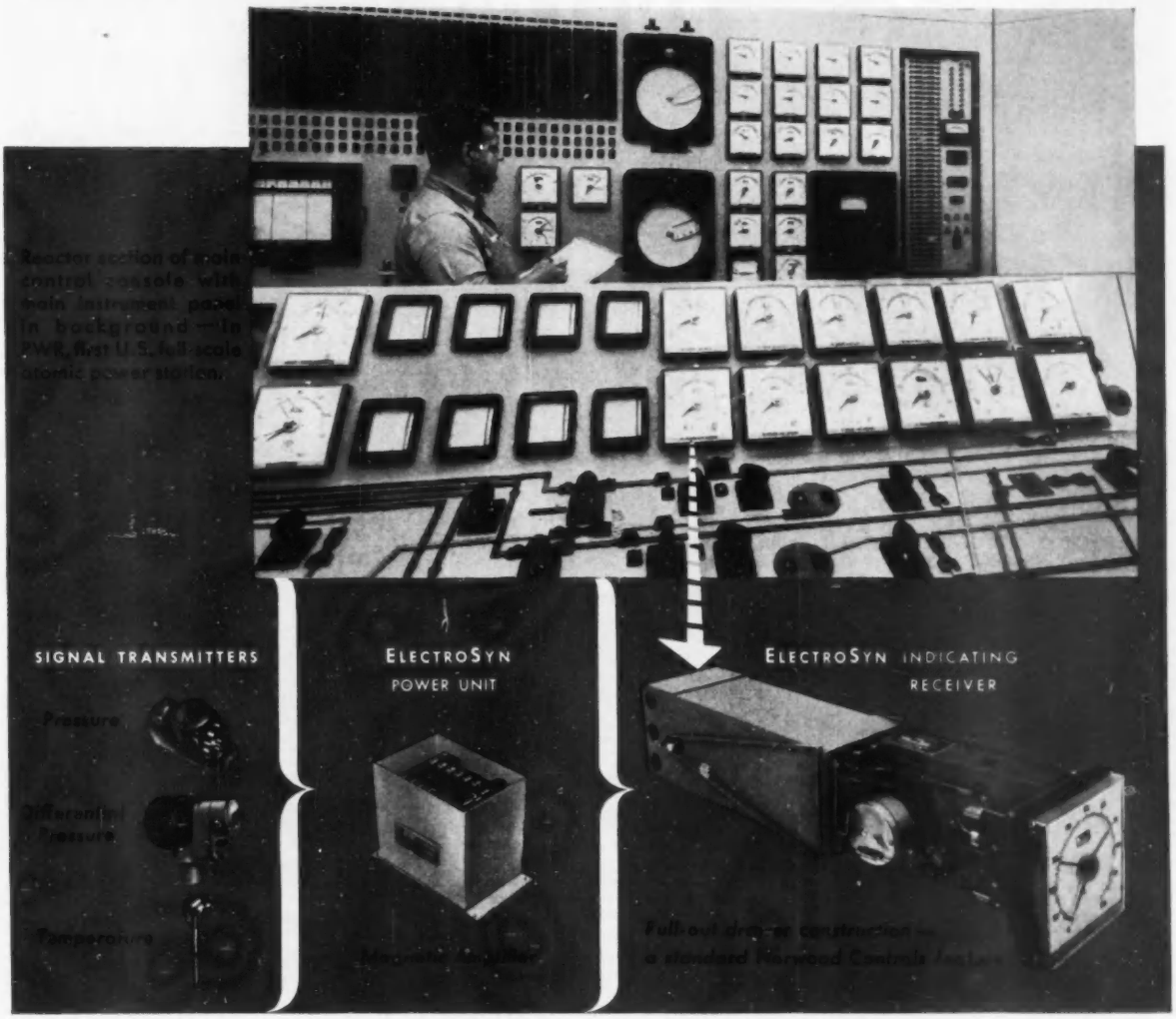
pressure • flow • temperature at Shippingport controlled by

NORWOOD CONTROLS

ELECTROSYN SYSTEM



Norwood Controls' **ELECTROSYN SYSTEM** and other special Norwood instrumentation control the primary reactor plant at Shippingport. ElectroSyn is a reliable, rugged, flexible, completely electro-magnetic null-balance system designed for a wide variety of applications in the atomic, chemical processing and gas and petroleum refining and transmission fields. At PWR it measures, indicates and controls pressure, flow, level, temperature, etc.

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AMERICAN-Standard PRODUCTS

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DETROIT CONTROLS DIVISION

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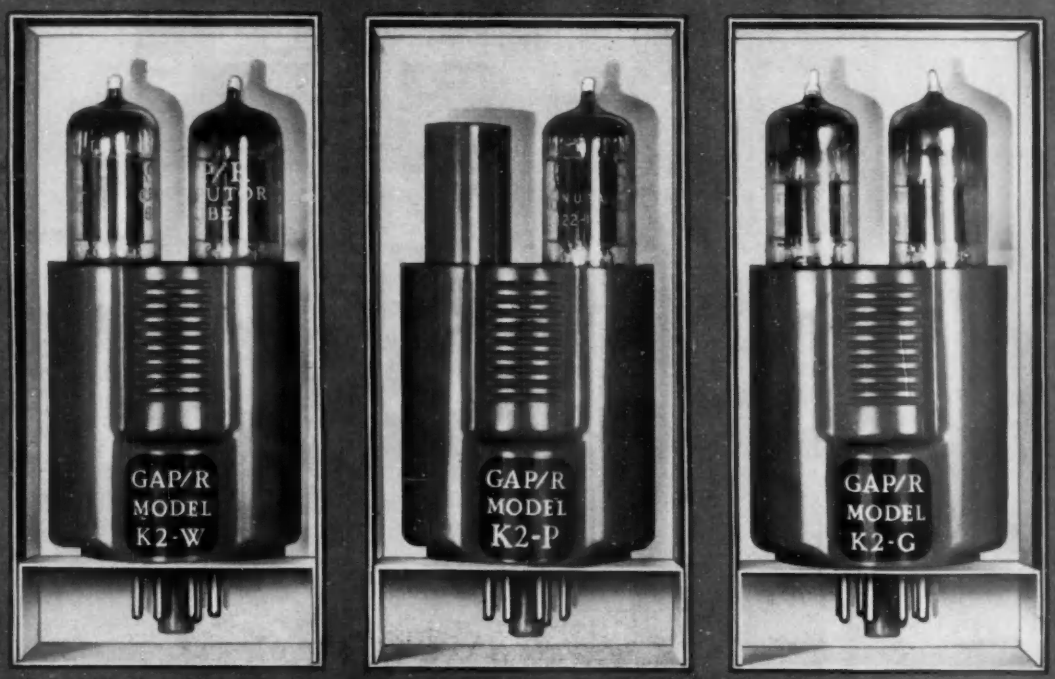

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PHILBRICK uses these octal plug-in modules, and many others like them in their standard computing instruments. They are tried and true, compact, convenient, and economical. You too can find profit and happiness with their help . . . . . *All K2 Plug-ins run on plus and minus 300 VDC and 6.3 VAC. Socket wiring is simple and standardized. Write for freely given opinions on your application.*

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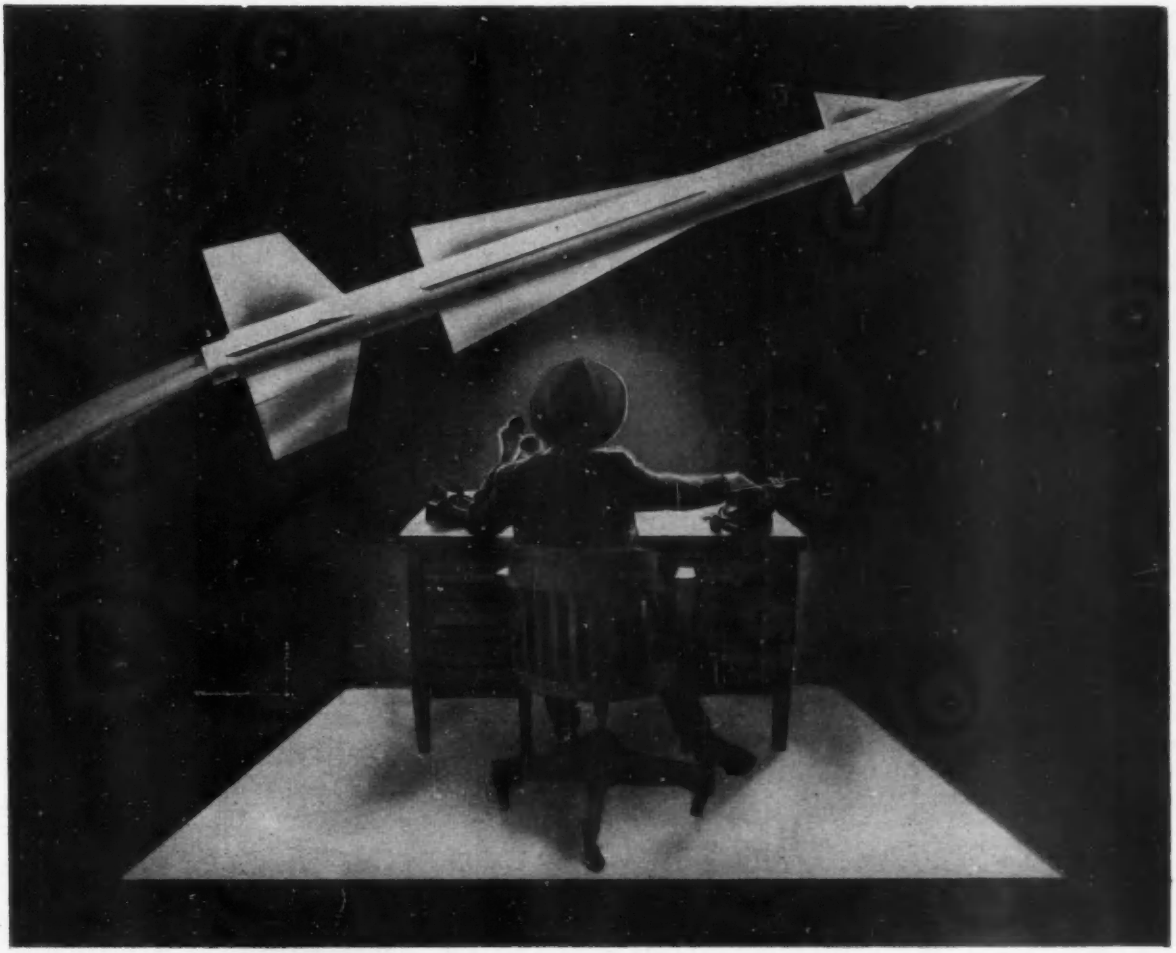

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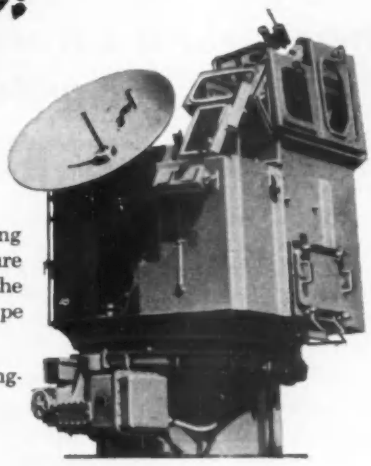
. . . must be accurate . . . must be reliable

These Qualities are the Standard for Engineering and Production at Daystrom Instrument.



Our engineers and production specialists working together as a hard-hitting team have established an outstanding performance record in the manufacture of Radar Antenna Pedestals and related intelligence equipment. We have the necessary machine tools and other facilities to get the job done on a prototype or volume production basis.

We can meet your immediate requirements or help you plan for your long-range needs.

Contact us now for complete information about our qualifications in the Radar Intelligence field.

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ARCHBALD, PENNSYLVANIA

In the wind tunnel of the Naval Supersonic Laboratory at M.I.T., a missile model is subjected to speeds of several Mach numbers. B-L-H SR-4 bonded wire strain gages report longitudinal and latitudinal stresses, drag, lift, etc., with high accuracy.

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There is an easy way to measure accurately any forces involving tension or compression, torque, etc. B-L-H SR-4® electronic transducers are compact, highly responsive, and extremely durable. Stock units offer lasting accuracy of ±1/10% and repeatability of ±1/20%. With appropriate instrumentation, they can determine center of gravity, weigh loads at rest or in motion, control batch and continuous processes, and record all data required. The type and number of applications are virtually unlimited.

The heart of every B-L-H transducer is its SR-4 bonded wire strain gages. They are bonded to a metal element in the transducer and approximately 10 milliamperes is fed through them. They receive the same strains as the transducer when a force is applied. Their electrical resistance changes in linear relationship with strain. Voltage output can be calibrated directly in terms of load—or fed into any common types of instrumentation, such as dial indicators, graphic recorders, digital printers, computers, etc.

For more information on B-L-H electronic transducers—load cells, pressure cells or torque meters—ask to have a B-L-H man call on you or write to Dept. 6-E for a copy of Bulletin 4300.

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Electronics & Instrumentation Division

Waltham, Mass.

SR-4® strain gages • Transducers • Testing machines

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4257

NOW! END READOUT CONFUSION...

with the new KIN TEL digital voltmeter

ANOTHER FIRST FROM KIN TEL! Here is a digital voltmeter that shows numbers on a readable single plane! With KIN TEL's new design, there are no superimposed outlines of numbers in the picture...no confusion caused by dials and old style numerical readouts. This digital readout uses a simple projection system – provides 7,000 to 8,000 hours of lamp life, compared with 100 to 200 hours for ordinary readouts.

FIRST OF A COMPLETE LINE OF DIGITAL INSTRUMENTS! Others include: Converters for measuring AC, ohms, ratios...multiple input scanners... serial converters to drive typewriters and punched tape units.

WIDE APPLICATION! KIN TEL digital instruments are ideal for automatic check-out systems for missiles and rockets; computer measurements; process control monitoring; production testing; test system calibration; strain gage, thermocouple and other transducer measurements, and calibration of laboratory and industrial electronic instruments.

Talk to your local KIN TEL representative. Sales and service everywhere. Or write us direct for further information.

See the difference!

ORDINARY READOUT

KIN TEL READOUT

CLEAR AND SHARP. ANY WAY YOU LOOK AT IT

- *100 Microvolt Sensitivity*
- *Automatic, Continuous Standard Cell Calibration*
- *High Reliability*
- *0.0001 to 999.9V—Plus Automatic Decimal and Polarity Indication*

SPECIFICATIONS

Display...Four (4) digit with automatic polarity indication and decimal placement. Total display area 2" high x 7.5" long, internally illuminated. Individual digits 1.25" high.

Automatic Ranges...0.0001 to 999.9 volts covered in four ranges.

Accuracy...0.01% or 1 digit, whichever is larger.

Counting Rate...30 counts per second, providing average balance (reading) time of 1 second, maximum balance time of less than 2 seconds.

Reference Voltage...Chopper-stabilized supply, referenced to an unsaturated mercury-cadmium standard cell.

Input Impedance...10 megohms, all ranges.

Output...Visual display, plus print control. Automatic print impulse when meter assumes balance. No accessories required to drive parallel input printers.

Input...115 volt, 60 cycle, single phase, approximately 75VA.

Dimensions...Control unit, 5¼" high x 19" wide x 16" deep. Readout display, 3½" high x 19" wide x 9" deep.

Weight...Approximately 40 lb.

Price...$2,100

Over 10,000 KIN TEL instruments in use today!

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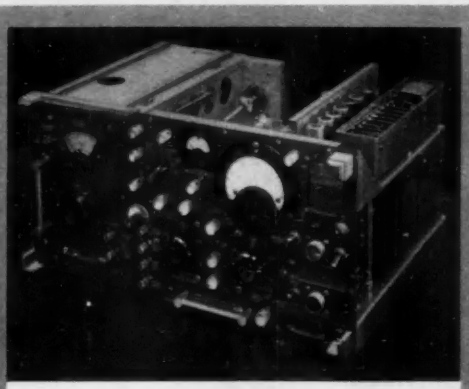
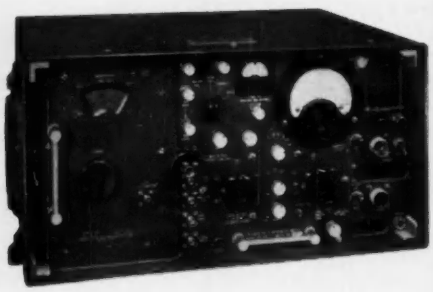
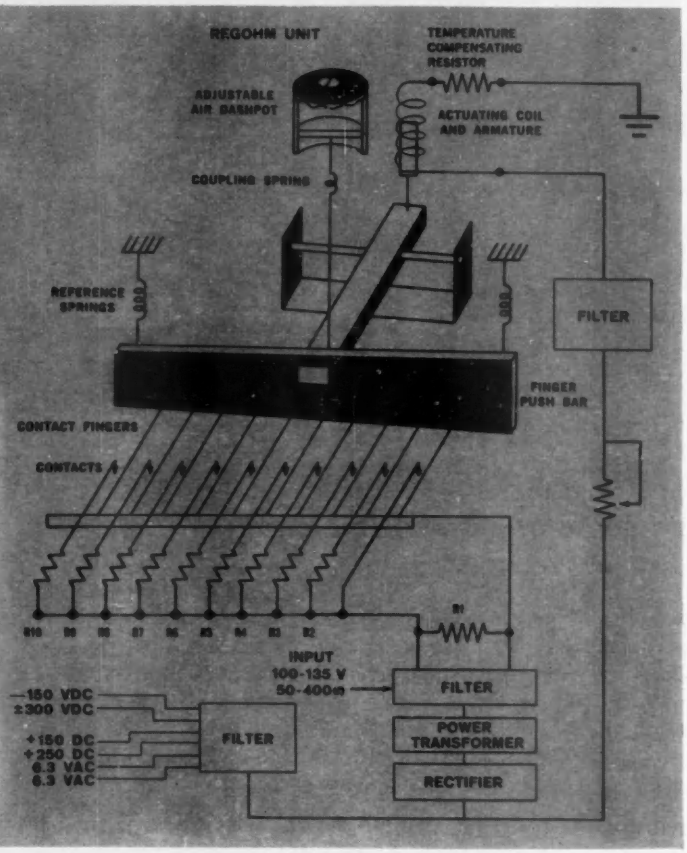
A Division of Cohu Electronics Inc.

REGOHM SOLVES Another Electronics Control Problem







REGOHM REGULATOR GIVES EMPIRE NOISE METER PRECISE AC INPUT—FROM LINE OR BATTERY

Empire Devices Products Corp. uses the compact Regohm regulator as the heart of the voltage control system in its Noise and Field Intensity Meter, Model NF-105. This meter is a precision instrument, covering the frequency ranges from 14 to 1000 MC, and is noted for its outstanding reliability and calibration stability.

The essential requirement of a closely controlled power supply is met by a unique regulator system that was developed by Empire and Electric Regulator engineers jointly. This control circuit, with elements shown in the accompanying schematic, holds the instrument's supply at the pre-set characteristics, although the external power supply may vary from 50 to 400 cycles, and potential from 100 to 135 volts. The wide range of regulated inputs permits precise measurements with this meter under severe field conditions and aboard aircraft as well. Frequently, when utility lines or other AC sources are not available, the instrument is powered with batteries working through an unregulated inverter.

Empire Devices regards the dependable Regohm circuit as a main factor in the Meter's unparalleled performance which has such high acceptance in both military and commercial circles around the world. The remarkable record of nine years in top-flight service proves both the excellence of the Empire Devices' design and the Regohm's durability and capacity for sustained performance.

Manufacturers of control and many other types of electronic equipment are finding answers in the Regohm's exclusive combination of: Sensitivity, Stability, Wide Range of Control Resistance, Long Life, Light Weight, Permanent Adjustment, Freedom from Maintenance, Rugged Design, and *Low Cost*. Our engineers will gladly discuss with you how Regohm may simplify your design, performance, and cost problems. Please call, wire, or write: **Electric Regulator Corporation, Norwalk, Connecticut.**

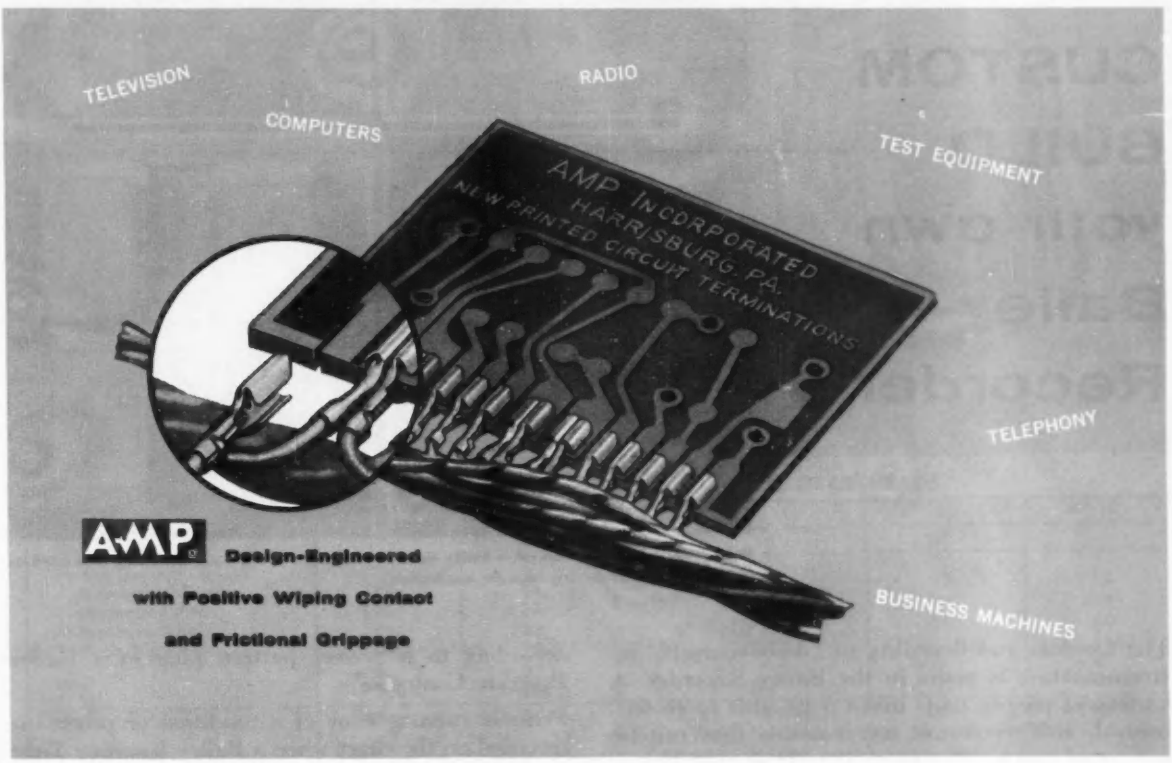
Please write for design, data and performance specs on REGOHM multi-stage regulators in applications similar to this.

REGOHM®

ELECTRIC REGULATOR CORPORATION

NORWALK CONNECTICUT

AMP-EDGE HAS THE EDGE ON PRINTED CIRCUITS



The new AMP-Edge Connector gives you . . .

greater flexibility— your printed circuit area and completed unit are not limited by the size of connection, as found in alternate methods of edge connection.

greater design versatility— they can be applied in any arrangement to any section of the perimeter of the printed circuit.

two-way cost reduction— production time and material costs are reduced through solderless termination of the connector to the wire (4,000 terminations per hour) and the ease of applying the Edge Connector to the printed circuit without molded parts.

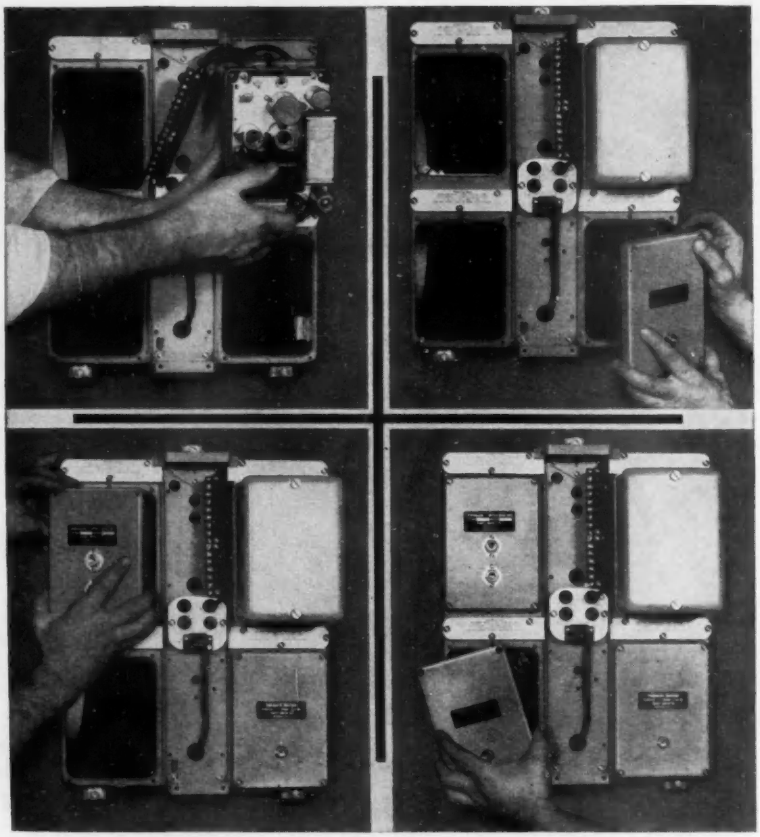
Additional information is available upon request.

AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

A-MP products and engineering assistance are available through wholly-owned subsidiaries in: Canada • England • France • Holland • Japan

CUSTOM BUILD your own Bailey Recorder



These four views of the back of a Bailey Recorder show how four plug-in units may be added as needed to meet almost any recorder application.

The freedom and flexibility of "do-it-yourself" instrumentation is yours in the Bailey Recorder. A variety of plug-in units make it possible to record, control, and retransmit any variable that can be converted to a pneumatic or electric signal.

The basic plug-in units are the Bailey a-c and d-c Electronic Receivers and Pneumatic Receivers. Any four of these may be used in one recorder, intermixed in any way, to provide four continuous records on one chart.

For automatic control, other plug-in units are available.

For square root extraction or linear integration, there are two plug-in variations of the Bailey Integrator.

When you want a pneumatic signal that varies according to a pre-set pattern plug in a Bailey Program Controller.

Periodic running time of a condition or process is recorded on the chart when a Bailey Running Time Recorder is used.

These and other plug-in units are described in Product Specification E12-5. Some companies stock Bailey Recorder cases and assorted plug-in units. As instrumentation and control needs arise they build up the kind of recorder-controller required, using the proper plug-in units from stock. Unmatched versatility such as this means lower instrumentation costs.

For the complete story of how easily you can custom build this recorder to your needs, see your Bailey Engineer. G43-1

BAILEY METERS

Instruments and controls for power and process

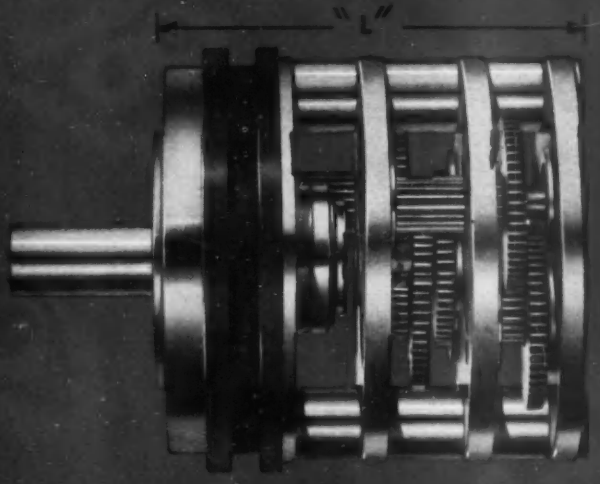
BAILEY METER COMPANY

1079 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

EDISON PRECISION GEAR HEADS

- Sizes 8 through 18 available in any ratio within 1%.
- Mount directly on all Edison and Bureau of Ordnance Motors without adapters.
- Adapters available to mount on any motor.

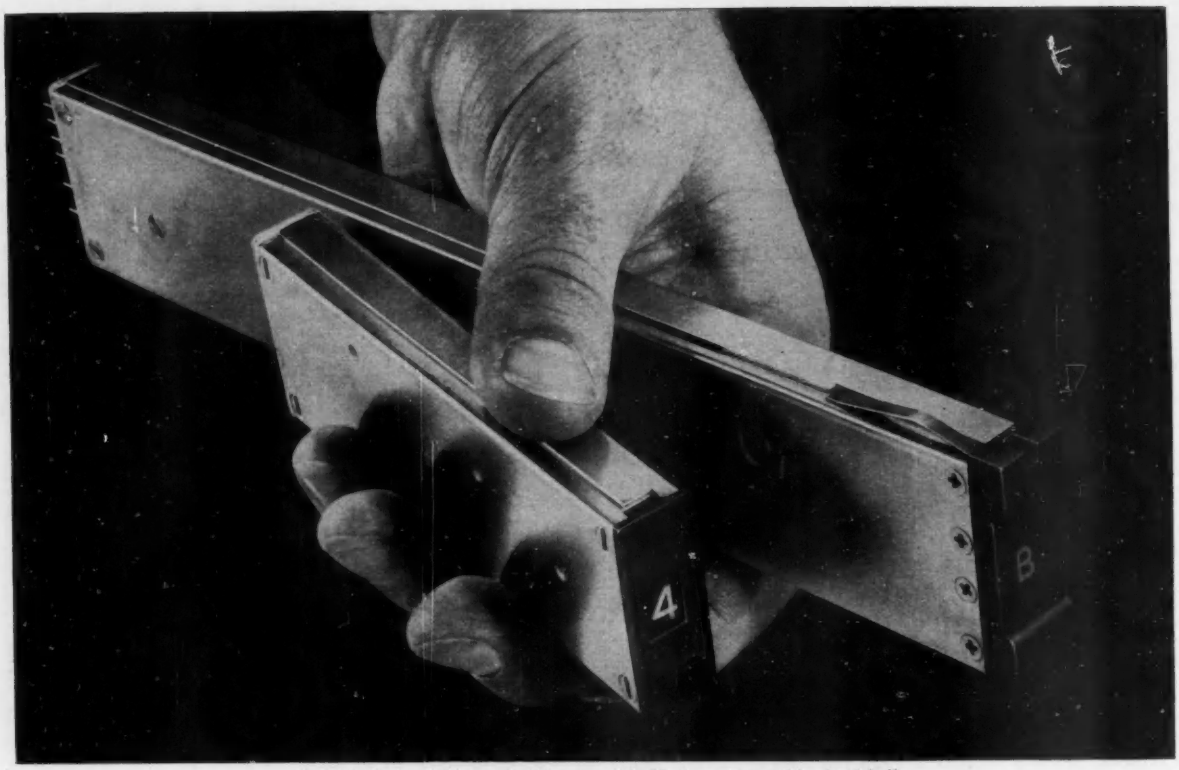


CHARACTERISTICS	STANDARD EDISON GEAR HEADS									
Size	8		10		11		15		18	
Part Number										
Pinion Data: Number of Teeth	12		13		13		15		15	
Diametral Pitch	120°		120°		120°		96°		96°	
Pressure Angle	20°		20°		20°		20°		20°	
Pitch Diameter	.1050" +.0 −.0005		.1083" +.0 −.0005		.1083" +.0 −.0005		.1562" +.0 −.0005		.1562" +.0 −.0005	
Gear Ratio to Length "L"	Ratio	"L"	Ratio		"L"	Ratio	Ratio	"L"	Ratio	
	17	0.750	31		0.781	36	40	0.812	60	
	42	0.812	93		0.954	108	140	1.000	240	
	104	1.008	280		1.054	324	490	1.100	960	
	253	1.070	840		1.116	972	1715	1.162	3840	
	615	1.204	2521		1.266	2916	6000	1.328	15,360	
	1494	1.347	7565		1.409	8748	21,000	1.487	61,440	
	3629	1.421	22,696		1.500	26,244	73,500	1.600	245,760	
Moment of Inertia GM CM²	.01		.018		.02		.05		.08	
Maximum Running Torque in. oz.	15		15		20		25		25	
Maximum Stall Torque in. oz.	35		35		40		50		50	
Breakdown Torque in. oz.	.01		.01		.012		.015		.018	
Backlash maximum	30'		30'		30'		30'		30'	

Gear Tolerances: Precision Class 2 AGMA 236.02. *Bearings:* Stainless Steel ABEC Class 5 or better. *Shaft Radial Play:* .002"/inch length max. with 4 ounce gage load. *Shaft End Play:* .002" max. with 1 pound gage load. Friction Slip Clutch available on request. Designed to meet applicable paragraphs of MIL-E-5272.

Thomas A. Edison Industries
INSTRUMENT DIVISION
38 LAKESIDE AVENUE, WEST ORANGE, N. J.

McGRAW EDISON



Digital indicator (left) can display a possible 16 characters and is about half the size of the Alpha-numerical indicator (right) which displays 64 characters.

UNION INDICATORS
permit direct readout of binary data

UNION Digital and Alpha-numerical indicators are controlled by binary code signals employing a minimum number of control wires, and respond to simultaneous binary switching combinations.

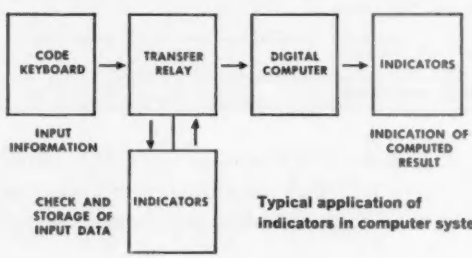
These indicators are electro-mechanical, D.C.-operated, readout devices for displaying characters in accordance with a predetermined code. The character display may be made to suit user's requirements.

Indicators are designed for plug-in mounting in a row so that data or messages of any desired length can be stored, displayed or transmitted at will. The indicators can be applied to the output of digital computers, teletype receiving equipment in conjunction with a buffer storage unit, telemetering systems, or wherever data needs to be displayed.

Two important features of these indicators are their inherent storage and transmitting characteristics which provide for data entry and retransmission. The indicators can be used to accept data from a source, free the source for other programs, and disseminate the data from one indicator to another as required. For each binary bit stored, an external relay can be eliminated.

UNION indicators have provided economic and reliable advantages in data display applications associated with Air Traffic Control, Navigation, Telemetering, Fire Control and similar Airborne and Surface Instrumentation displays.

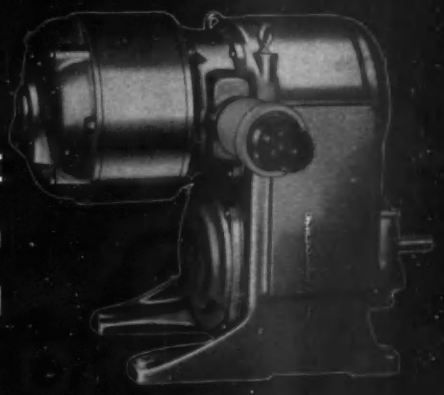
Write for Bulletin No. 1015 for complete information.



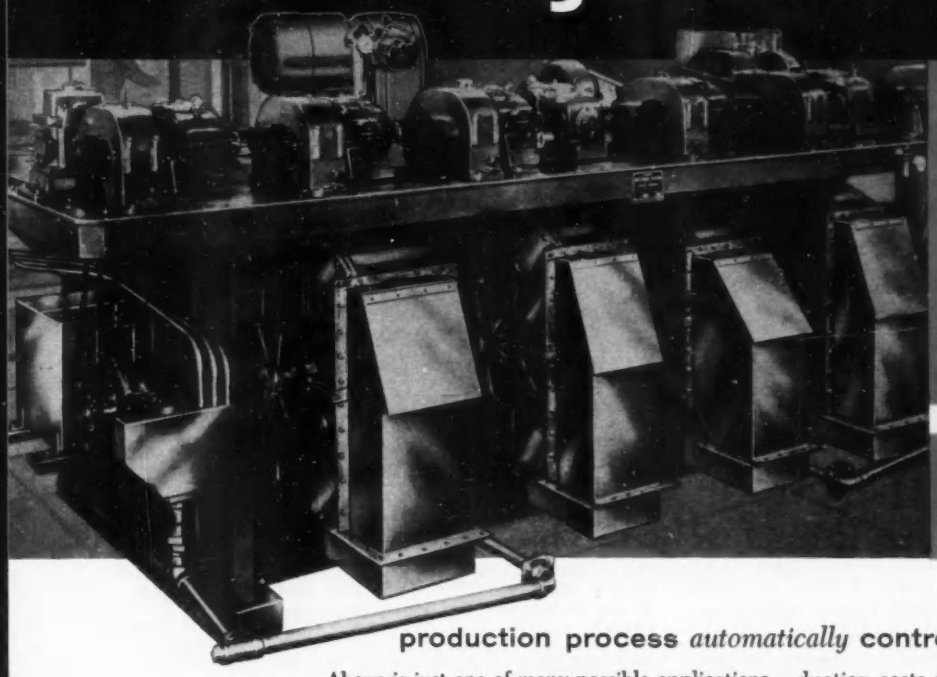
Typical application of indicators in computer systems.

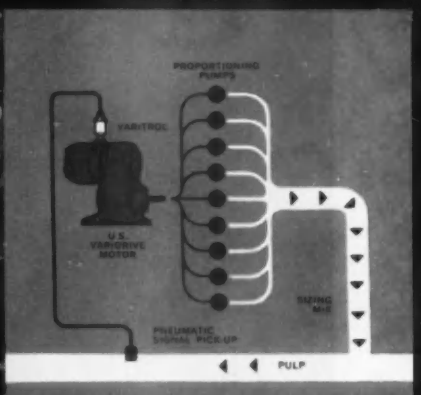
UNION SWITCH & SIGNAL
DIVISION OF WESTINGHOUSE AIR BRAKE COMPANY
PITTSBURGH 18, PENNSYLVANIA

U.S. VARIDRIVE
MOTOR with
VARITROL rpm control



automatically proportions 10 ingredients!





Pneumatic signal from pulp flow operates Varitrol to speed or slow U.S. Varidrive Motor, thus speeding or slowing 9 proportioning pumps to maintain proper mix.

production process *automatically* controls AC motor speeds

Above is just one of many possible applications of VARITROL pneumatic controls to save manpower and increase quality. Picking up a signal from the production process, VARITROL speeds up or slows down the U.S. VARIDRIVE motor to maintain pre-set product standards—in this case, proper proportions of 10 ingredients in making newsprint paper. VARITROL can control many basic industrial operations, using a signal from the process to correct speeds. A U.S. automation expert will be glad to survey your production process and advise how VARITROL can save production costs and improve quality. Varidrive motors are available in RATINGS 1 TO 60 H.P.

Production Process itself corrects motor speeds to maintain Pre-set Tolerances in such variables as:

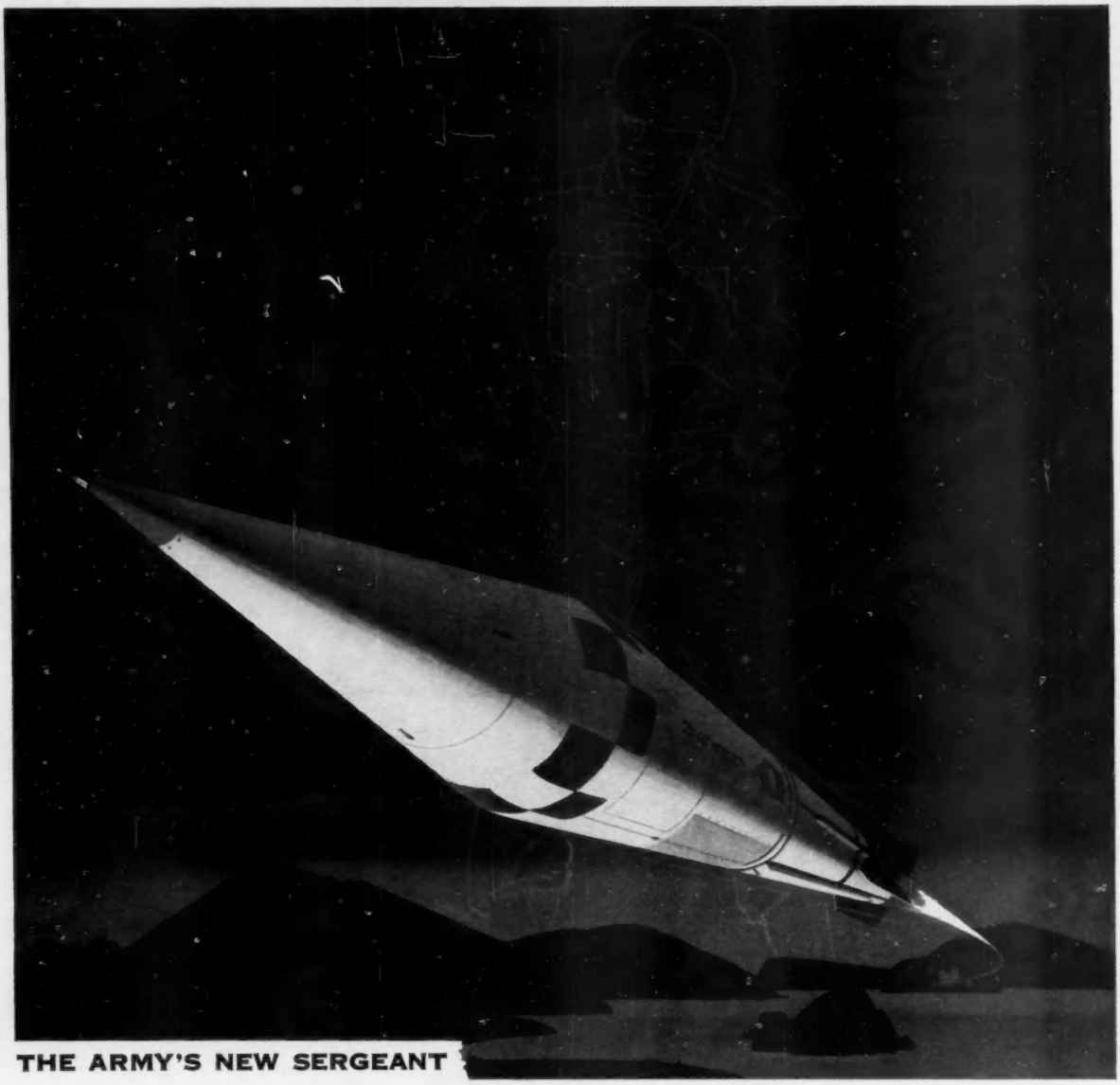
WEIGHT • HEAT • HUMIDITY • PRESSURE
TORQUE • LIQUID LEVEL • RE-WIND TENSION
SPEED SENSITIVITY (CONSTANT SPEED)
SYNCHRONIZATION • PROPORTIONAL FLOW

U.S. ELECTRICAL MOTORS INC.

P. O. BOX 2058, LOS ANGELES 54, CALIFORNIA
OR MILFORD, CONNECTICUT

FREE ILLUSTRATED BROCHURES...
Send for Controlled Speed Systems Booklet and 8-page full color illustrated Varitrol brochure.

NOTABLE ACHIEVEMENTS AT JPL...



THE ARMY'S NEW SERGEANT

JPL is proud to have the responsibility of designing and developing the U.S. Army's newest operational missile system—the Sergeant. This weapon is America's first truly "second generation" surface-to-surface tactical missile and, when placed in production will eventually succeed the Corporal which was also a JPL development.

The Sergeant, especially designed as an extremely mobile tactical weapon, utilizes a solid propellant rocket motor which provides better field handling and storage capabilities than those of many other weapon systems. It can deliver a nuclear blow deep into enemy territory and its highly accurate guidance system is invulnerable to any known means of enemy countermeasure.

All elements of the Sergeant are particularly designed for active field use with emphasis on reliability, mobility and the use of standard U.S. Army vehicles wherever possible. The erector-launcher, for example, is capable of rapid movement over rough terrain. These characteristics place in the hands of the U.S. Army an important new tactical element of extended range.

The basic activity at JPL continues to be—research into all scientific fields related to the development of weapons systems and space research vehicles.

CAREER OPPORTUNITIES NOW OPEN IN THESE FIELDS

ELECTRONIC, MECHANICAL, CHEMICAL AND AERONAUTICAL ENGINEERING • PHYSICS AND MATHEMATICS

jpl

JET PROPULSION LABORATORY

A DIVISION OF CALIFORNIA INSTITUTE OF TECHNOLOGY

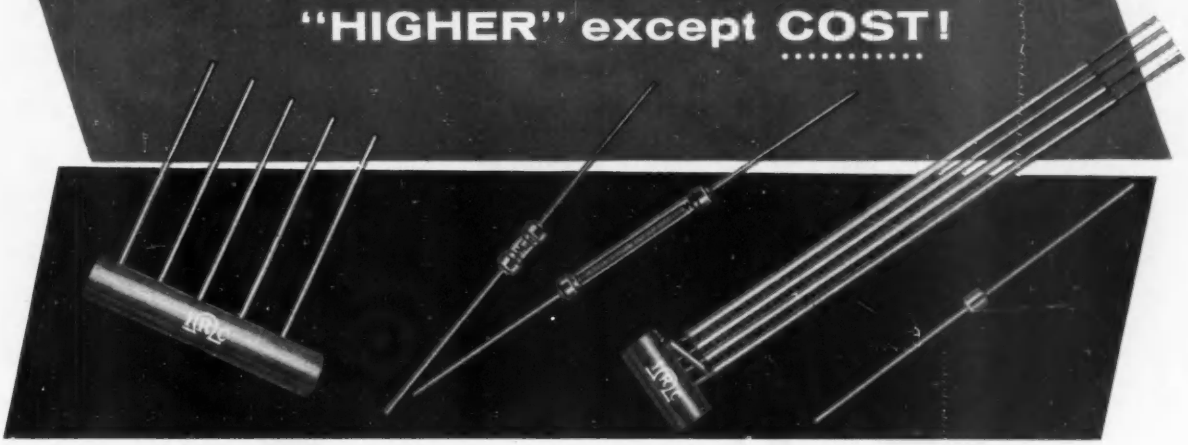
PASADENA • CALIFORNIA

Microstak

SELENIUM DIODES

every important feature rated

"HIGHER" except COST!



Available in molded plastic, hermetically sealed glass and other enclosures, Microstak Selenium Diodes give you the *top performance* you want in low current power supplies, arc suppressors, voltage regulators, balanced modulators, meter overload protection, logarithmic converters, magnetic amplifiers and many other applications.

Microstak Selenium Diodes provide:

HIGHER voltage—up to 8000 peak inverse volts—available with cell stacking, while silicon and germanium are limited to around 600 volts for single diode

HIGHER inverse resistance than germanium

HIGHER ambient temperature operation than germanium—up to 125°C

HIGHER reliability—no catastrophic failures as in other semi-conductors

HIGHER solderability with IRC exclusive alloy plating

But, their cost is **LOW**—these units are economical to buy and to use.

Yes, by replacing diode vacuum tubes with Microstak Selenium Diodes you can get all these features and more besides. You can now save *space*, as well as money, in many low current applications calling for high back resistance and low forward resistance—Microstak components eliminate all the bulk, sockets and assembly connected with tubes.

Microstak Selenium Diodes come in single or multiple cell types . . . are supplied to much closer limits than ordinary diodes . . . show improved stability over a wide temperature range.

For more information send for Bulletin SR-1A.

IRC®

INTERNATIONAL RESISTANCE CO.

Department 243, 401 North Broad Street
Philadelphia 8, Pennsylvania, U.S.A.
In Canada: International Resistance Co., Ltd., Toronto, Licensee

MINIATURIZED Electro-Magnetic COUNTER

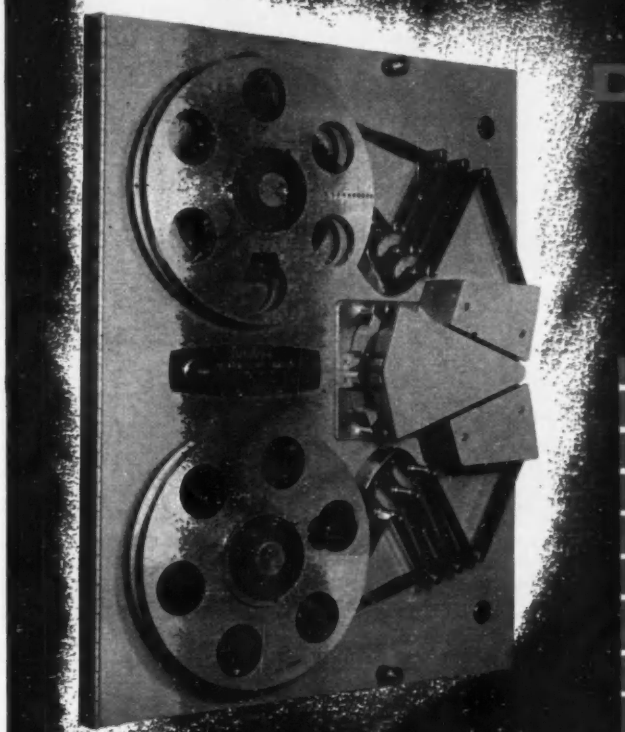
Newest News from VEEDER-ROOT

Series 1527 Veeder-Root Miniaturized Electro-Magnetic Counters were originally developed for use in aerial cameras. These and similar counters are used to "post" the number of film-exposures, gallons or rounds of ammunition remaining after each use.

The new miniaturized counters present a frontal area less than 1" x 1" . . . save an important amount of space over the older, larger counters. Yet they are designed to operate at speeds as high as 900 counts per minute. And this modern design includes a new push-in bi-directional reset knob, with speed-up gearing. Specifications meet most military requirements. Write for full details.

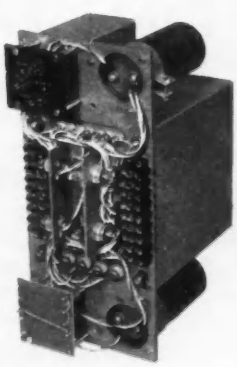
Added Evidence that Everyone Can Count on

VEEDER-ROOT
INCORPORATED
HARTFORD 2, CONNECTICUT
Hartford, Conn. • Greenville, S. C. • Altoona, Pa. • Chicago
New York • Los Angeles • San Francisco • Montreal
Offices and Agents in Principal Cities



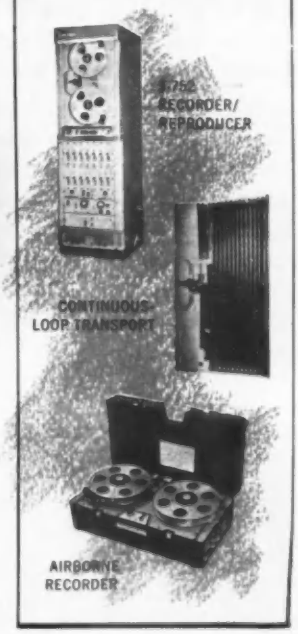
CEC announces the new **DataTape** *digital magnetic tape recorder/reproducer*

- *all transistorized electronics*
- *modular construction**
- *starts and stops in less than 5 milliseconds*
- *high-speed servo response*
- *continuous-duty servo motors*
- *all-metal-surface magnetic heads* (½" SPACING BETWEEN READ AND WRITE HEADS)
- *uses ½" to 1¼" tape*
- *10½" reels with NARTB hubs*
- *designed for standard rack mounting*
- *size: 19" wide by 24½" high by 13" deep*



NOW AVAILABLE... Not merely a laboratory instrument, but a fully ruggedized, reliable digital recorder designed for a whole gamut of industrial applications where long periods of unattended operation with minimum maintenance and down-time are paramount. Standardized speeds, track-width and spacing, and start and stop distances assure complete compatibility with other digital tape transports and handlers. *Contact your nearby CEC field office for complete information,* or write for Bulletin CEC 1608-X8.

**Modularized components, such as Power Supply Unit at right, permit instant access and easy maintenance or replacement with minimum down-time.*

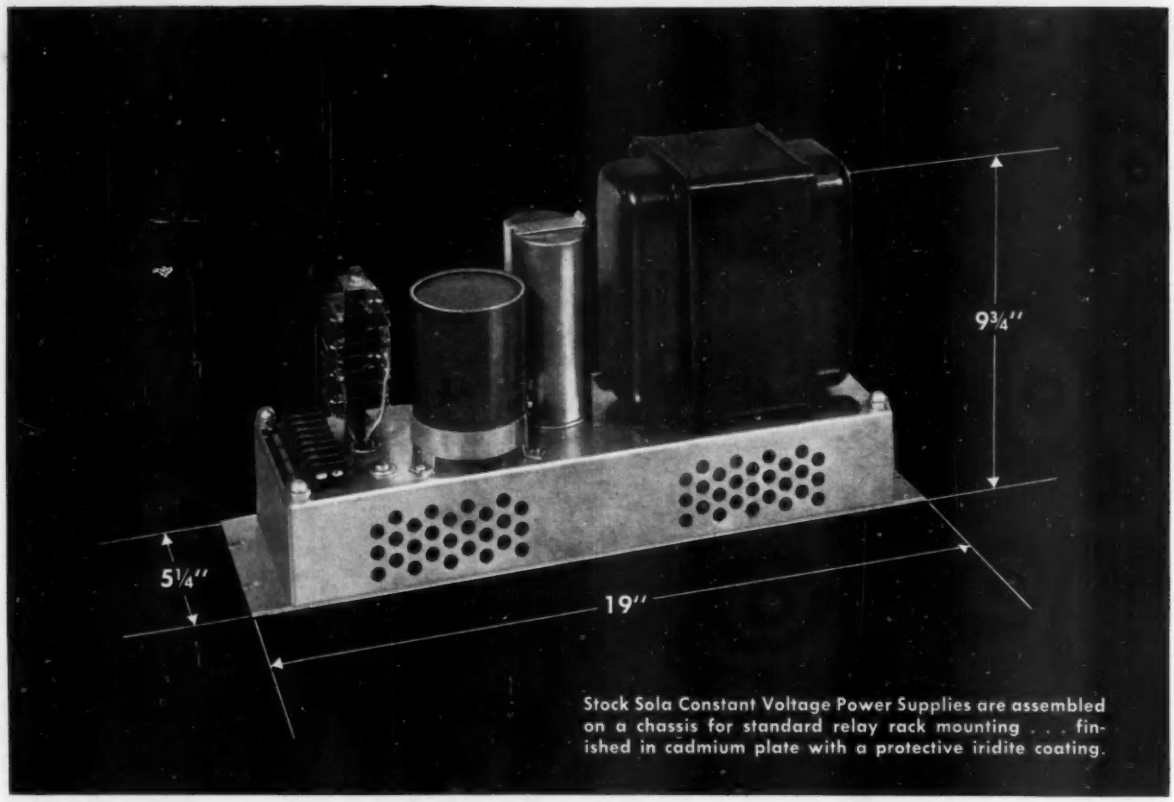


DataTape Division

Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD



Stock Sola Constant Voltage Power Supplies are assembled on a chassis for standard relay rack mounting . . . finished in cadmium plate with a protective iridite coating.

COMPACT, regulated DC power supply

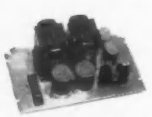
Looking for a source of regulated dc power that fits into a little space? If so, then you'll find the Sola Constant Voltage DC Power Supply is just what you want.

You'll also like to know that this space-saver is a top performer too. It's ideal for intermittent, variable or pulse loads. It delivers current in the "ampere range", regulates within ±1% with up to 10% line voltage variation, has less than 1% rms ripple, and even tolerates dead shorts. This dc power supply is 80% efficient and has an output impedance which is very low.

How's it done? Well, the answer is a unique combination of three components. A special Sola Constant Voltage Transformer is teamed up with a semiconductor rectifier and a high-capacitance filter. The Sola transformer's electrical characteristics maximize most of the advantages of the rectifier and filter, while virtually eliminating all their disadvantages. The resultant regulated dc power supply is simple, highly reliable, compact and moderately priced.

Fixed output — six ratings available from stock

Adjustable output — six ratings from stock



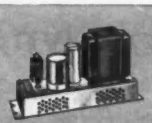
Custom-designed units produced to your specs

Write for Bulletin 26E-DC-235

Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill., Bishop 2-1414 • Offices in Principal cities • In Canada, Sola Electric (Canada) Ltd., 24 Canmotor Ave., Toronto 14, Ont.

SOLA

CONSTANT VOLTAGE TRANSFORMERS

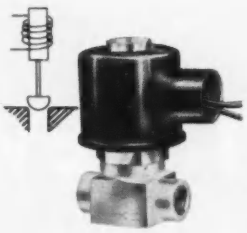


REGULATED DC POWER SUPPLIES

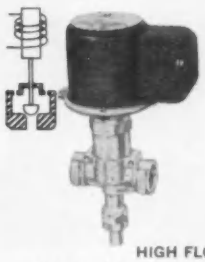
MERCURY LAMP TRANSFORMERS

FLUORESCENT LAMP BALLASTS

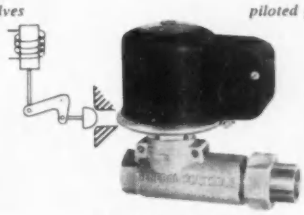
these six basic valves will meet any electric valve requirement you have



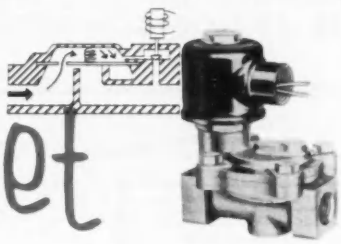
GENERAL PURPOSE
direct acting solenoid valves



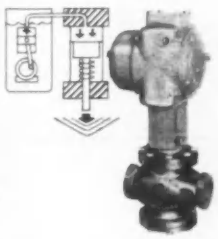
HIGH FLOW
piloted piston solenoid valves



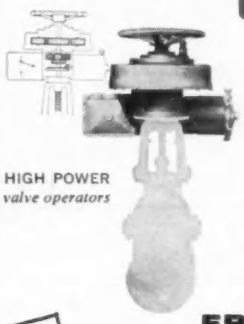
HIGH PRESSURE
lever action solenoid valves



HIGH FLOW
magnetic diaphragm valves



HIGH VOLUME
HIGH PRESSURE
Hydramotor valves



HIGH POWER
Tork-Master valve operators

FROM 1/8" TO 60" PIPE SIZE

- normally open
- normally closed
- three-way
- four-way
- two-wire or three-wire control
- explosion-proof and weatherproof
- special body and seat materials
- odd voltages AC and DC
- UL, FM and AGA approvals

And with these GENERAL CONTROLS valves you get not only a complete range of sizes . . . but the right combination of operator *and* valve to do the job right . . . in terms of operating power, speed, capacity, flow characteristics and safety. You'll find the answer to your every electric valve problem in these GENERAL CONTROLS valves. Send for basic electric valve catalogs today.

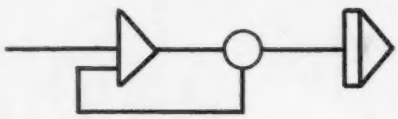
GENERAL CONTROLS

Manufacturers of America's Finest Automatic Controls for Home, Industry and the Military

Glendale, Calif. • Skokie, Ill. • Guelph, Ontario, Canada

Six Plants—42 factory branch offices serving the United States and Canada

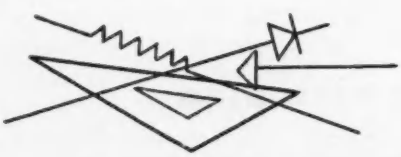
for THAT NEW IDEA



IN ANALOG COMPUTING

IN ANALOG PLOTTING

IN DIGITAL PLOTTING



IN CONTROL SYSTEMS ENGINEERING

Write Dept. CE-5

Detailed information can be obtained by mail, wire or telephone

Electronic Associates, Inc.

Manufacturers of PACE *Precision Analog Computing Equipment*

LONG BRANCH, NEW JERSEY

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Austerity Prompts Detroit To Take a Second Look

In Detroit engineering circles today, the word "austerity" is heard more frequently than "automation". Car company executives are putting pressure on their manufacturing groups to look hard and long at new control developments before a dollar is spent.

Production race postponed

With all production races postponed indefinitely, the manufacturing boys have plenty of time for doing just that. Ask one of them what he thinks of some revolutionary new control widget and chances are that he'll hand you an already completed study of that very thing. And a sober study it will be, clear of any traces of "blue sky."

"You can't spend ten dollars to save one" says a top GM engineer in summing up the austerity program. With literally billions of dollars of machines and equipment, his company doesn't want to replace a single one of them unless someone is sure the new machine will pay off. Sounds obvious enough. Yet, it's only recently that the car firms awoke to the fact that a large percentage of transfer machines were being scrapped (because of product changes) before they could be fully depreciated.

Transfer Machines?

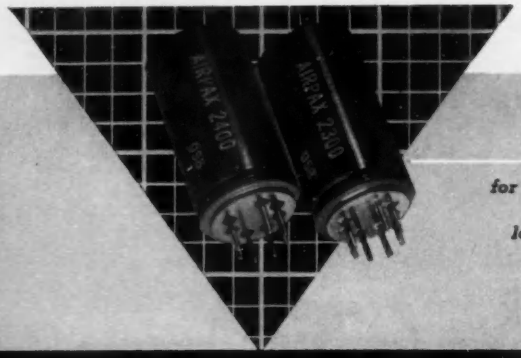
The result is a joint effort by the Big Three to require that transfer machines be built up from standard modules and that the modules of different manufacturers be interchangeable. Thus, when a given production run is completed after a year or two, transfer machines can be rebuilt and used again.

Standards are being written in other areas, too—and many of their provisions are aimed in the direction of design economy and interchangeability. Chrysler, for example, has just issued a standard for resistance welder controls. Next in line for such treatment are press controls.

Numerical Control?

Despite some unprofitable experiences, Detroit is still wedded to the transfer machine and its "conventional" fixed-cycle control system as the ultimate in automatic production. This weakens the case for putting numerical controls on the production floor. Some engineers are willing to speculate on possibilities "in the distant future," such as one involving engine manufacture and assembly—processes that have been complicated tremendously by customer options on power ratings and accessories. In the Chrysler Division alone, for example, there are 182 variations of the same basic engine. Flexible program control could be the answer.

The car companies do recognize numerical control as a valuable adjunct to tool room equipment. But cost is a roadblock.

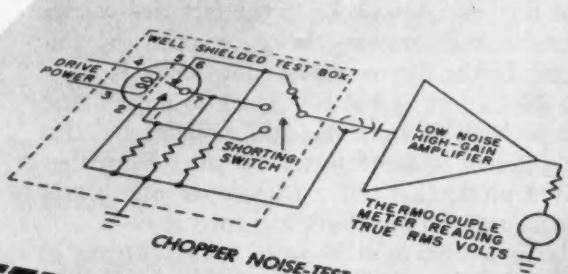


LOW-NOISE CHOPPERS

for null-seeking servos and instrument amplifiers hold wide-band noise in the low microvolt range. This unusually low level is achieved by chopper construction. Even lower levels can be obtained in narrow-band applications by filtering.

Low-Noise Choppers —from Airpax!

Airpax choppers Types 2400 (60-CPS) and 2300 (400-CPS) are specifically designed for use in low-level modulators. In most cases it is below the instrument background noise.



CHOPPER NOISE-TEST CIRCUIT

CHOPPER CHARACTERISTICS

DRIVE: *6.3 volts RMS*

LIFE: *greater than 5,000 hours in usual applications*

CONTACTS: *0 to 2 milliamperes at 0 to 100 volts into resistive load*

CASE: *hermetically sealed with 7-pin miniature base and drive coil leads out top—same size as other Airpax standard miniature choppers*

DESIGNERS AIRPAX PRODUCTS COMPANY ENGINEERS

Airpax Products Company, Cambridge Division, Jacktown Road, Cambridge, Maryland

Puncturing a balloon

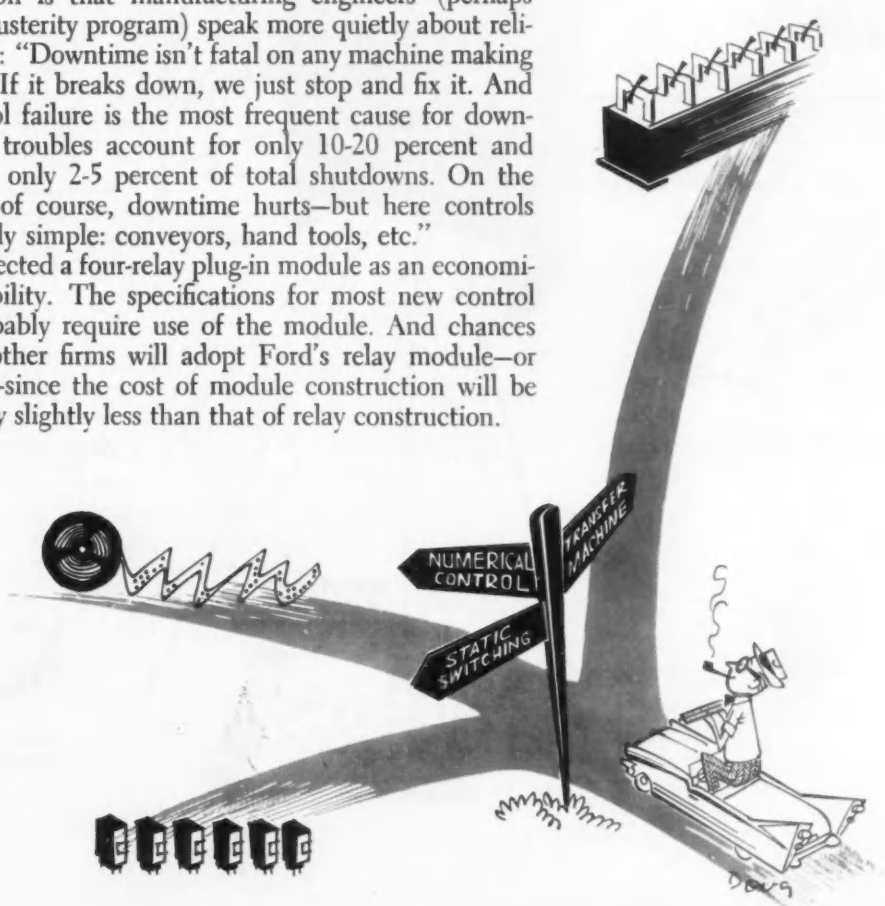
Impediments have been found too in an area many control system builders looked upon as a "natural" for application of contouring control. It had been thought that equipment using such controls could drastically reduce "lead-time", the 200,000 or more man-hours needed to convert a clay model into production dies. But Ford's George Pascoe and others have found that the control people were over-optimistic. The major problem is that the clay model does not contain all the information needed for making a die. The model serves only as a base to which styling, body-design, manufacturing and die-making engineers add extensive modifications before a real working part can be produced.

Static Controls?

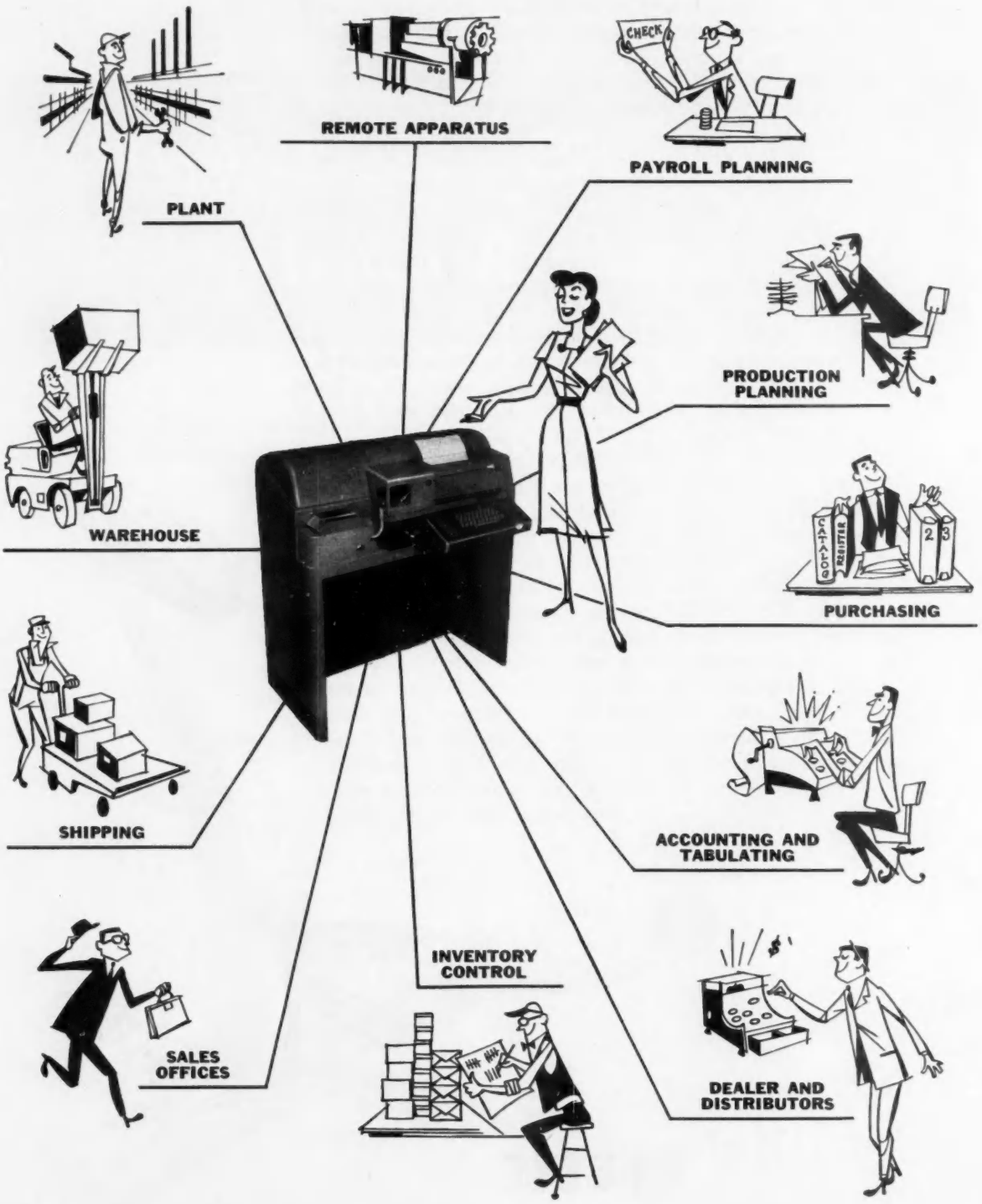
All of the Big Three have made extensive investigations into static controls. A good variety of production equipment—including some small transfer machines—has been and is being equipped with static panels. But there is certainly no clear cut swing away from relay controls. One obvious reason is the greater cost of the static control—as much as four times more than that of an equivalent relay panel if magnetic amplifier output is used. And, there is no size advantage in static panels over relay panels. Add to this some problems in reeducating service personnel (who apparently like to add an interlock or limit switch now and then—a move that is simple to accomplish with a relay panel but more difficult with static designs).

Another reason is that manufacturing engineers (perhaps because of the austerity program) speak more quietly about reliability. Says one: "Downtime isn't fatal on any machine making parts for stock. If it breaks down, we just stop and fix it. And we find that tool failure is the most frequent cause for downtime; electrical troubles account for only 10-20 percent and relay difficulties only 2-5 percent of total shutdowns. On the assembly lines, of course, downtime hurts—but here controls are comparatively simple: conveyors, hand tools, etc."

Ford has perfected a four-relay plug-in module as an economical aid to reliability. The specifications for most new control panels will probably require use of the module. And chances are good that other firms will adopt Ford's relay module—or some variation—since the cost of module construction will be equal or possibly slightly less than that of relay construction.



New Teletype Set



ties them together

At 100 words per minute

New Teletype Model 28 ASR Automatic Send-Receive Set . . . for your communication and data processing needs.

Here is a "packaged" set—a single, compact console with a complete array of facilities—to serve as a center for your message transmission and paperwork simplification systems.

Facilities for typing . . . tape punching . . . tape transmission . . . tape reception . . . sending and receiving "page" copy on message paper or multi-part business forms . . . tape as a by-product of both incoming and outgoing messages . . . a host of remote controls. All customized to *your* requirements.

Operates like a typewriter for preparing invoices, shipping papers, etc.—but at the flick of a switch it goes "on-line" to tie together all your departments, all your plants—individually or in combination.

The Teletype Model 28 Automatic Send-Receive Set is NEW in every way:

- **New Compactness.** Never before so many facilities in so small a space. Console measures only 39 inches high, 36 inches wide, 18½ inches deep, with keyboard projection of 4½ inches.

- **New Speed.** Typing, transmission at 100 words per minute. Off-line tape punching at higher speeds.

- **New Features.** Feature-packed for IDP and communications operations . . . The Teletype Model 28 ASR offers NEW approaches to more efficient applications: (a) for the first time, *all* your punched tape can have the characters typed right on it —so it can be read and handled easily, by anyone in your organization; (b) "robot brain" Stunt Box—a miniature unit that is actually a built-in switching and remote control system; (c) facilities for translating electronic impulses from business machines into printed messages for office use or transmission to other locations.

Requires less maintenance, too. Designed, like all Teletype equipment, for dependable "round-the-clock" service; the Model 28 ASR is equipped with all-steel clutches that need oiling only twice a year, plus other features that assure low maintenance. This is important to operating efficiency whether you prefer to buy or lease your Teletype equipment.

For more information, write to Teletype Corporation, Dept. 20-E, 4100 Fullerton Avenue, Chicago 39, Illinois.

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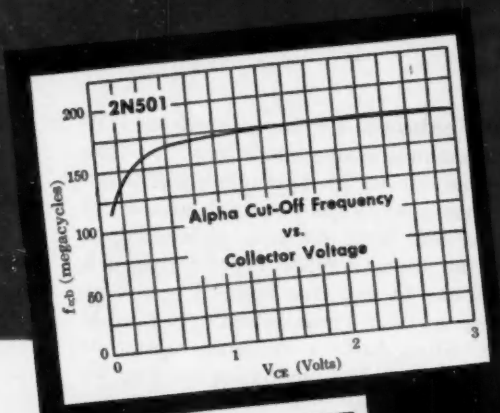
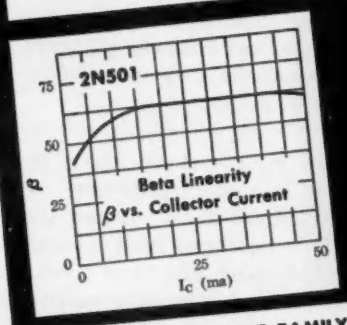
VHF Transistors! First From PHILCO





New family of Micro Alloy Diffused-base Transistors (MADT)*

- **Rise, Storage, Fall Time in Low mμsec Range**
- **High Oscillator efficiency at 200 mcs**
- **Amplifier gains of 10 db at 200 mcs**

MADT FAMILY APPLICATIONS DATA

TYPE*	f_{max}	Power Gain	Oscillator Efficiency	Class of Use
2N499	250 mcs (min)	10 db at 100 mcs	25% at 100 mcs (min)	oscillator and amplifier to 100 mcs
2N500			25% at 200 mcs (min)	oscillator to 400 mcs
2N501	Ultra high-speed switch typical t_r = 12 mμsec; (18 max.); t_s = 7 mμsec; (12 max.); t_f = 4 mμsec; (10 max.). In circuit with current gain of 10 and voltage turnoff.			
2N502†	500 mcs	10 db at 200 mcs		amplifier to 250 mcs
2N503†		11 db at 100 mcs(min.		amplifier to 100 mcs
2N504	50 mcs	46 db at 455 KC		high gain IF amplifier

*Available in voltage ratings up to 35V.
†In JETEC TO-9 Case (widely known as JETEC 30 Case).

Here is a major breakthrough in the frequency barrier . . . a new family of *field-flow* Micro Alloy Diffused-base Transistors. Philco MADT's extend the range of high gain, high frequency amplifiers; high speed computers; high gain, wideband amplifiers and other critical high frequency circuitry.

MADT's are available to various voltage and frequency specifications for design of high performance transistorized equipment through the entire VHF and part of the UHF spectrum. These transistors range in f_{max} from 250 mc to as high as 1000 mc. MADT gains are typically 10 db at 200 mc and greater than 16 db at 100 mc. A low cost general purpose unit is available which will deliver typically 18 db at 50 mc and 32 db at 10 mc.

Make Philco your prime source of information for high frequency transistor applications.

Write to Lansdale Tube Company, Division of Philco Corporation, Lansdale, Pa., Dept. CE-553

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PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

Control ENGINEERING

MAY 1958

Trade Groups Contribute, Too

All engineers know how technical societies contribute to professional excellence, by offering platforms for presentation of technical advances and by sponsoring ASA standards of technical terminology and practice. But how many know about the supplementary efforts of trade associations? In the control field trade associations concentrate on test procedures, terminology, and standards-of-manufacture for products offered by their member manufacturers. Because these efforts directly affect the usability of the products, they merit the control engineer's recognition, critical examination—and demand for more.

The work of three trade associations stands out:

• *National Electrical Manufacturers Association* has published "Standards for Industrial Control" which covers such products as limit switches, synchros, relays, voltage controllers, and motor controllers. NEMA is currently completing standardization of symbols for static-switching elements and circuits.

• *Electrical Industries Association* (formerly RETMA) has held two conferences on numerical control and automatic production and has set up technical committees to practically blanket the control field. The new eight-channel punched-tape standard came from on EIA committee.

• *Scientific Apparatus Makers Association's Recorder/Controller Section* has published nine industry product standards, two tentative product standards, and one tentative standard on terminology for accuracy and sensitivity. In addition, it has set up annual awards, totaling $600, for the best instrument application papers appearing in the *ISA Journal*.

Other trade groups that have projects under way:

• *National Fluid Power Association*—ratings and terminology for hydraulic equipment.

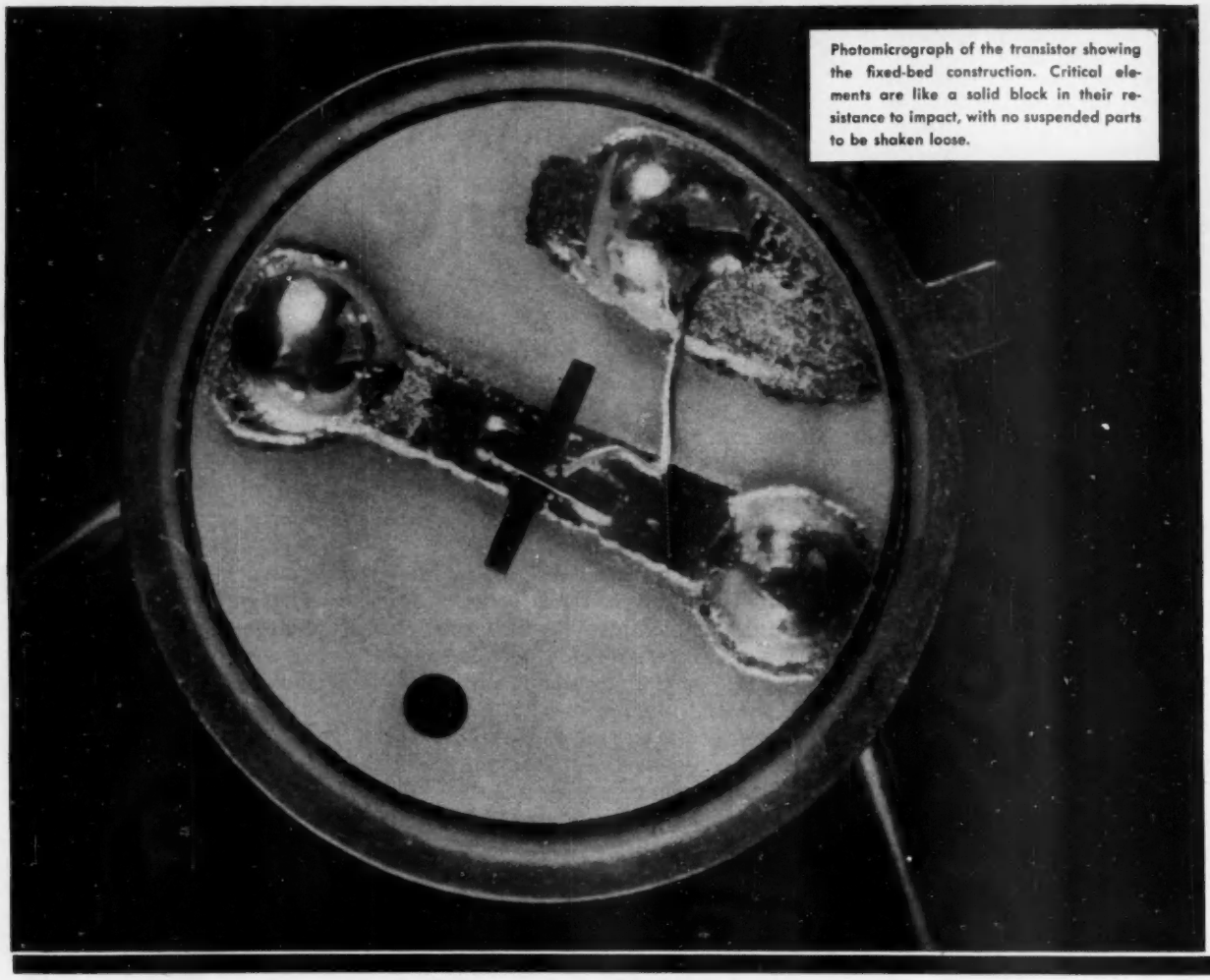
• *Scale Manufacturers Association*—terminology for mechanical scales and electronic load cells.

• *Fluids Controls Institute*—tests for valve capacity and leakage. (In 1955 it adopted terminology for power-actuated valves.)

As far as we know, SAMA—Rec/Con's awards for technical excellence are unique; we'd like to see more of this sort of encouragement of technical excellence. We'd like to see more activity in standardization of hydraulic controls. In fact, we'd like to see all trade associations shouldering their share of the standardization load as conscientiously as ASA and the technical societies.

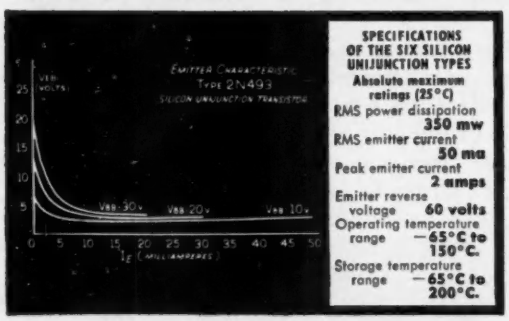
W. E. Vannah

New fixed-bed mounting withstands



Photomicrograph of the transistor showing the fixed-bed construction. Critical elements are like a solid block in their resistance to impact, with no suspended parts to be shaken loose.

New data on the silicon Unijunction transistor



SPECIFICATIONS OF THE SIX SILICON UNIJUNCTION TYPES

Absolute maximum ratings (25°C)

RMS power dissipation	350 mw
RMS emitter current	50 ma
Peak emitter current	2 amps
Emitter reverse voltage	60 volts
Operating temperature range	−65°C to 150°C.
Storage temperature range	−65°C to 200°C.

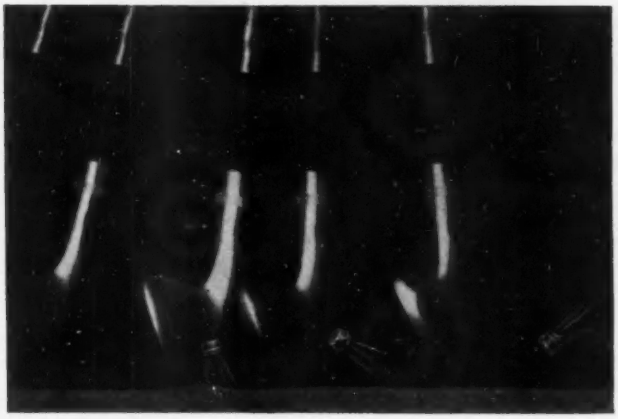
The unijunction features open-circuit-stable negative resistance characteristics. In switching and oscillator applications, one unijunction not only does the work of two transistors with less circuitry, but the circuit is also more stable over a wide temperature range.

To help you in your use of the unijunction, a new series of curves has been developed as shown. It points up emitter characteristics at different base-to-base voltages. The unijunction is also the first G-E transistor to be converted to the new impact-resistant Fixed-Bed Mounting process as described above.

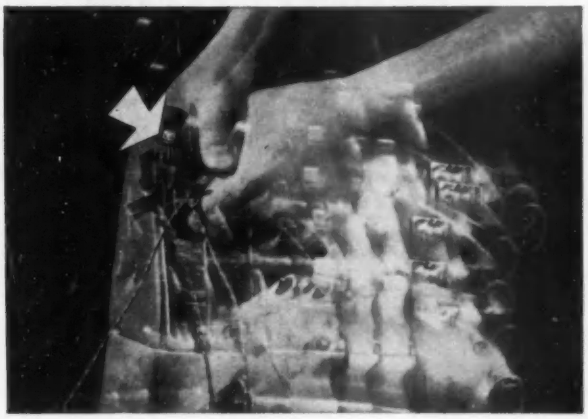
Please send for complete data on the six unijunction types — sample circuits, theory and specifications.

YOUR G-E SEMICONDUCTOR SALES REPRESENTATIVE will be glad to give you further information and specifications on General Electric transistors and rectifiers. Spec sheets, bulletins, and other data can also be obtained by writing Section S1658, Semiconductor Products Dept., General Electric Company, Electronics Park, Syracuse, N. Y.

tremendous impact and vibration



"GOLF CLUB TEST" General Electric transistors with Fixed-Bed Mounting have been struck full force with a No. 2 Iron. After traveling forty yards, tests showed they still worked perfectly.



"JACKHAMMER TEST" Another G-E transistor with Fixed-Bed Mounting was taped to a pneumatic drill, which was then operated for ten minutes. When the transistor was removed, tests showed it still worked perfectly.

Ceramic disk guards against major causes of transistor failure

In General Electric's new Fixed-Bed Mounting, critical elements of the transistor are welded flat on a disk of ceramic. Thus any impact must be great enough to damage the disk itself before transistor failure can occur. In conventional methods of manufacture, impact need only penetrate the transistor's metal case in order to damage the standard upright header.

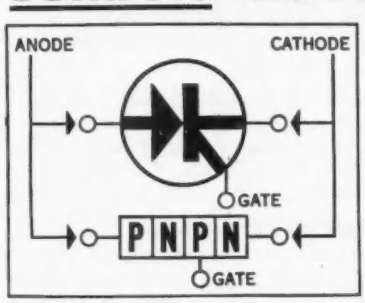
Because of their many suspended parts, standard upright headers are also subject to inertial stress at a number of points. General Electric's Fixed-Bed Mounting eliminated *all but one* of those parts—the suspended aluminum emitter lead. And this is provided with enough slack to absorb inertial stress, with connection points so securely welded that the unit withstands far more than the military centrifuge test of 20,000 G's.

To eliminate thermal stress, the coefficient of expansion of G.E.'s ceramic disk has been made equal to that of the semiconductor metal. Previously, enough "play" had to be allowed to absorb alternate expansions and contractions, thereby reducing the strength and stability of the unit.

The Fixed-Bed Mounting's electrical elements lie flat, in close contact to the transistor case, providing greater heat conduction out through the case. Therefore, the fixed-bed construction cuts down junction temperature, making it possible to double the power dissipation of the same transistor made with upright-header construction.

Fixed-Bed Mounted units have exceeded all standard shock, centrifuge and temperature-cycling tests. General Electric's unijunction transistor (see below) now has this feature.

New G-E Controlled Rectifier rectifies and controls current up to 5 amperes at 300 v.



The controlled rectifier is a four-layer silicon device with a "gate" to which a signal can be applied to control forward current. It can handle more than one kw of power.

NEED A FEW SEMICONDUCTORS IN A HURRY? Check your local G-E distributor *first*. You'll find his delivery, service facilities and prices are hard to beat.

General Electric's new silicon controlled rectifier acts like a thyratron. In the reverse direction, it's a standard rectifier. But it will also block forward current until either a critical breakover voltage is exceeded or a signal is applied to the third lead. Then it switches to a conducting state and acts as a forward-biased silicon rectifier.

The controlled rectifier can be actuated by a little as 15 mw. Breakdown occurs at speeds approaching a microsecond, after which voltage across the device is so low that current is determined by the load. This enables the user to control a large anode-to-cathode current with an extremely small amount of power, or to switch power from high impedance to low impedance in microseconds.

Applications include replacement of relays, thyratrons, magnetic amplifiers, power transistors and conventional rectifiers. Sample quantities of the controlled rectifier are now available. Prices will be sent on request.

GENERAL ELECTRIC

-hp- voltmeters for every need

-hp- 410B — 20 cps to 700 MC, ac or dc coverage, also dc VTVM with over 100 megohms input impedance, or ohmmeter 0.2 to 500 megohms. Ac measurement input capacity 1.5 $\mu\mu$f, input impedance 10 megohms. Standard voltmeter of electronics industry. $245.00.

-hp- 400H — 1% accuracy to 500 KC, ±2% to 1 MC, ±5% full range. 10 cps to 4 MC; 5" mirror scale meter, range 0.1 mv to 300 v. 10 megohm input impedance minimizes loading. 56 db amplifier feedback insures highest stability. $325.00.

-hp- 400AB—high value multipurpose VTVM. 10 cps to 600 KC, range 0.3 mv to 300 v, 11 ranges. High stability, sensitive, accuracy ±2% to 100 KC. 10 megohm input impedance. Reads direct in volts, dbm. $200.00.

-hp- 400D, best VTVM value built. 10 cps to 4 MC, accurate within ±2% to 1 MC, range 0.1 mv to 300 v. Reads direct in v, dbm. High 10 megohm input impedance prevents circuit loading. New 56 db feedback amplifier circuit insures highest stability. $225.00.

Data subject to change without notice. Prices f.o.b. factory.

-hp- 400L LOGARITHMIC VOLTMETER

High accuracy
5" true log voltage scale
10 cps to 4 MC
12 db linear scale
10 db range steps
Generous scale overlap

New Model 400L's logarithmic voltage scale plus long scale length provides an instrument of maximum readability and an accuracy which is a *constant percentage of the reading.* Voltage scales are more than 5" long, with a 12 db scale spread across the full scale length. The meter is mirror backed for maximum accuracy. A range switch changes voltage sensitivity in 10 db intervals. This feature, together with the 12 db scale, provides generous overlap and is of particular convenience in work involving decibel levels. Accuracy is ±2% of reading or ±1% of full scale, whichever is more accurate, to 500 KC.

Features of the new 400L include 0.3 mv to 300 v range (12 steps, 1-3-10-30 sequence), high stability, 10 megohm input impedance, large overload capacity, compact size. The instrument is also a stable amplifier. Model 400L (cabinet) $325.00; (rack mount) $330.00.

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FIELD ENGINEERS IN ALL PRINCIPAL AREAS

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Improving Fractionator Performance with Dynamic Analysis

FRED A. WOODS
Union Carbide Olefins Co.

THE GIST: From the standpoint of economical production, it is important to place a process under good control and on-stream as fast as possible. The field instrument man attempts to do this by means of simple controller-setting techniques that rely on practical process knowledge and experience rather than direct knowledge of process dynamics. If these do not give stability, the powerful but more complex technique of dynamic analysis must be tried by someone else, usually an instrument engineer, who has an understanding of the fundamentals of frequency response.

The point to be kept in mind is that dynamic analysis in the field is primarily an engineering tool to solve a production problem. Approximations to theory—assumptions about process data and shortcuts in using this data—can be safely made as long as they rapidly provide a fairly accurate and satisfactory combination of proportional, reset, and rate controller settings.

The author shows how an unstable fractionating column at his plant yielded a significant payout after dynamic analysis. He describes the process and the previous steps taken to control it, shows the justification for the valuable engineering time expended, and works out the controller settings from a step test and frequency-response diagrams. The engineering data is shown on two worksheets; the text explains the approach and interprets the answers.

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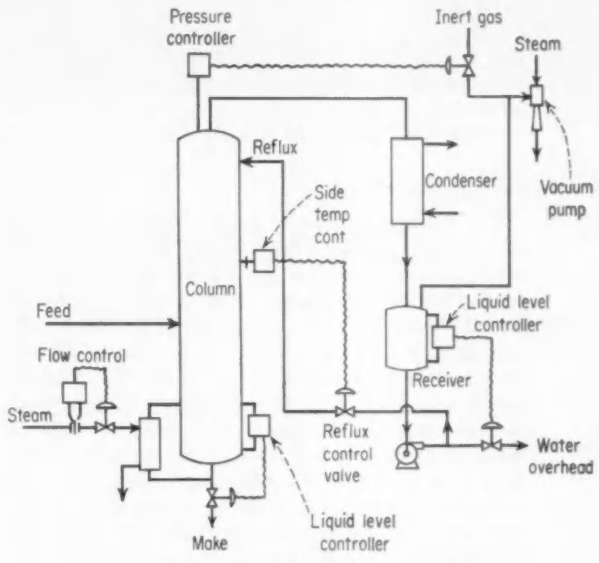

FIG. 1. Fractionating process that was improved by dynamic analysis.

On most jobs the field instrument man determines controller settings by means of simple rules and techniques; but these failed when it came to stabilizing the side temperature on a fractionation column which separates monoethylene glycol from water. Because of this, the process was operated manually for a long time, and suffered production losses. Finally the engineering department was called in.

The costs of the necessary dynamic test and analysis were easily justified. Monoglycol passes overhead with the water when the side temperature gets too high, and the result is loss in total production. When the side temperature gets too low, water contaminates the product, which then must be reprocessed through the fractionator. An hour's deviation from specifications, not unusual with manual control, was valued at $2 in lost or contaminated product. In addition, considerable time was spent by the operator watching and adjusting the side temperature or rerunning the product. The total loss was therefore more like $5 a day, which amounted to $1,800 a year, enough to bring in the

engineering department. Then it took only four engineering hours—valued at $50—to perform one test, reduce the data, compute stable controller settings, and observe operation to assure stability.

The fractionating column and its associated control loops are shown in Figure 1. The side temperature which controls reflux flow is an important part of the overall control because it is an inferential measurement of monoethylene glycol purity as obtained from the bottom of the column. The steam-flow controller determines the heat input to the column. One liquid level controller maintains a desired base level by varying the rate at which product (make) is removed from the column, and another controls the water condensate level in the receiver. All controls worked well except the side-temperature loop. Temperature oscillated widely, causing the product to deviate from specification.

Testing the column

Once it was decided to apply dynamic analysis to the stability problem, the question arose whether to use frequency-response or transient-response tests on the column. Frequency tests usually give all the data necessary to solve this type of problem. But considerable time and special equipment are required to obtain such data directly. Therefore the transient response to a step change of input was chosen. Such an approach requires first, that the test data be reduced to obtain the transfer function, including dead time and time constants, and then that it be converted to frequency response diagrams. Previous experience indicated that frequency response data thus derived is comparable in accuracy and resulting control to similar data obtained by direct measurement. Furthermore, transient tests require little time and, in addition to instrumentation already on the process, only a watch with a sweep second hand was needed.

The side-temperature control loop was opened—between the measured variable and the controller—by putting the controller on *manual*. The temperature first was held steady near the desired operating value, then, by a step-change of air pressure to the reflux control valve, was changed by an amount that might be expected in normal operation. The resulting step response was plotted point by point, Figure 2, from visual observation of the indicated temperature with respect to time, using the watch to accurately measure small increments of time. Also shown (insert in Figure 2) is the chart obtained on the recorder-controller during this test. The recorder-controller chart drive, fast enough for normal process recording, moves the chart too slowly for the test.

Analyzing the test data

The process frequency response is derived from Figure 2. Several interesting points can be immediately determined from this figure as it stands:

1. From zero time to point A is dead time, the time it takes for the temperature to show a detectable change to the step-change in reflux flow. The dead time τ_d is 3.0 min.

2. The transient temperature does not level off, indicating that the process does not have self-regulation within the limits of the transmitter range.

3. A plateau occurs at about 7 min, point *B* on Figure 2, during which the process behaves for a short time as if it were self-regulating.

Points 2 and 3 tell an interesting story. A self-regulating characteristic is presupposed in applying any transient response to the frequency-response conversion technique. Since this process is not apparently self-regulating, a leveling-off—the dashed-line plateau in Figure 2—must be assumed for determining the process time constants. Justification for this assumption may be had by adjusting the controller based on the derived dynamics, so that the process never deviates out of this region.

The reduction method applied in Figure 2 to obtain the time constants is called the *percent incomplete response technique*[2]. It is easy to use and precise enough for such applications as the one here. The detailed reduction is carried out in Figure 3 and in the text and table associated with that figure.

The time constants obtained from the reduction are τ_1 equal to 1.05 min and τ_2 equal to 0.37 min. These time constants and the dead time of 3.0 min may be attributed to individual portions of the overall process in the following way: the dead time is caused by the material's physical holdup on the trays between the top of the column, where the reflux is introduced, and the tray at which the temperature is measured. The larger time constant, 1.05 min, can be attributed to a readjustment of material composition in the condenser and on the trays. It is not a holdup, but a lag in change in fractionation. The smaller time constant, 0.37 min, can be attributed to the lag caused by the detector, thermowell, and transmission tubing used in measuring the temperature.

The static gain of a process is generally determined by measuring the net change in the process variable after it has finally leveled off, due to a known change in the controlled valve air pressure. But this is not possible in the present problem—the temperature does not level off and hence the final temperature is not known. Therefore, a final temperature must be assumed. Since the temperature is still rising at 100 deg C (chart, Figure 2), it is assumed that it will level off somewhere above that value, say 101 deg C. Thus, the static gain of the process is (101 − 82)/0.75, or 25.3 deg C/psi.

The transient response has now yieded all data necessary to set up the approximate transfer function of the process and associated temperature measuring equipment; that is, the frequency response of everything in the control loop except for the controller. Using standard frequency-response templates for each of the factors in the transfer function, the process

WORKSHEET I

EXTRACTING FREQUENCY-RESPONSE DATA FROM A TRANSIENT-RESPONSE TEST

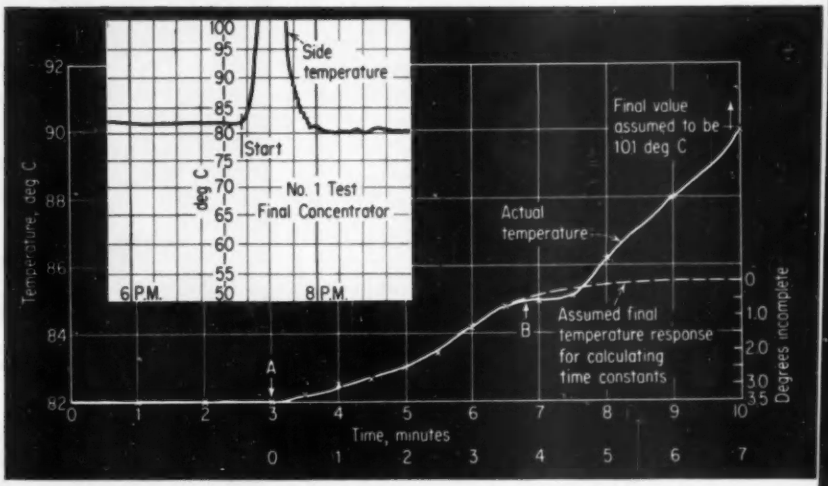

FIG. 2. Response to step change plotted with watch. Insert shows actual chart record of same response.

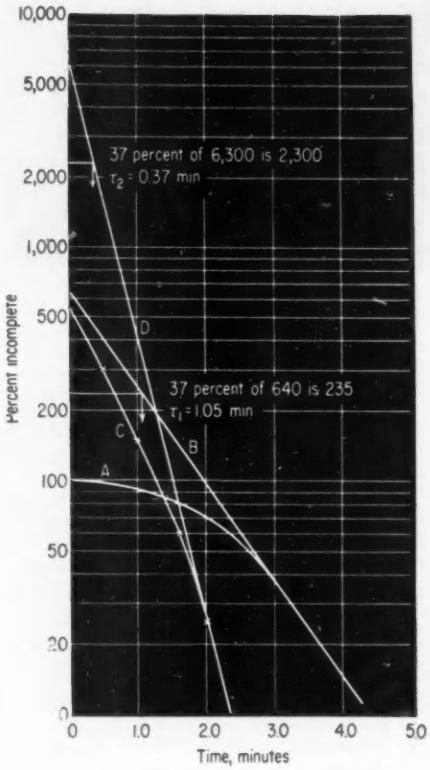

FIG. 3. Percent incomplete response technique yields process time constants.

CALCULATING PERCENT INCOMPLETENESS

Time, t min	Time, $t-\tau_d$ min	Incompleteness ratio	Percent incomplete
0	0		
1.0	0		
2.0	0		
3.0	0		
4.0	1	3.15/3.5	90
4.5	1.5	2.9 /3.5	83
5.0	2.0	2.5 /3.5	71
5.5	2.5	2.0 /3.5	57
6.0	3.0	1.3 /3.5	37
6.5	3.5	0.7 /3.5	20
7.0	4.0	0.5 /3.5	14
7.5	4.5	0.25/3.5	7.2
8.0	5.0	0.20/3.5	5.7

τ_1 = Time at 37 percent of first straight-line intercept: 0.37 × 640 = 235 = 1.05 min or 1/1.05 = 0.953 radians/min
τ_2 = Time at 37 percent of second intercept: 0.37 × 6,200 = 2,300 = 0.37 min or 1/0.37 = 2.7 radians/min
τ_d = 3.0 min or 1/3 = 0.33 radians/min

In Figure 2, the dead time of 3.0 min is easily determined. The time constants are found from the transient following the dead time; then, for simplicity, a new time scale, shown as the lower horizontal time scale, is used. Also added to the curve to help find the percent of the incompleted response is the degrees-incomplete scale at the right: at 83 deg C the response is 3.5 deg incomplete and at 85.5 deg it is zero deg incomplete. The percent incomplete is calculated at a convenient interval of (new) time, and the information plotted on the semi-log graph paper of Figure 3. The development of such information is shown in the table, which serves as an orderly intermediate step in transferring data from Figure 2 to Figure 3, curve A.

The percent incomplete response technique calls for extending the straight-line portion of Curve A back to the zero time axis, and then taking 37 percent of the vertical intercept. The time at 37 percent is the larger of the time constants, 1.05 min. To find the second time constant, Curve C, the difference between Curves B and A, is plotted. Ideally, Curve C should plot as a straight line for a second-order system. In this case, however, C is not a straight line and the assumed second time constant is found by extending the straight line portion of C back to the zero axis and taking 37 percent of the intercept. The time at this value, 0.37 min, is the second time constant.

The table shows the simple calculations involved in finding these time constants, and indicates that the reciprocals of the time constants and the dead time are found in radians per min. These latter values are the reference frequencies used in drawing the corresponding frequency-response plots, Figure 4, with standard templates. The main text contains the calculation of static gain and traces the development of the process transfer function from gain, dead time, and time constants. It also discusses the physical significance of each of these factors.

WORKSHEET II

CALCULATING CONTROLLER SETTINGS FROM FREQUENCY-RESPONSE CURVES

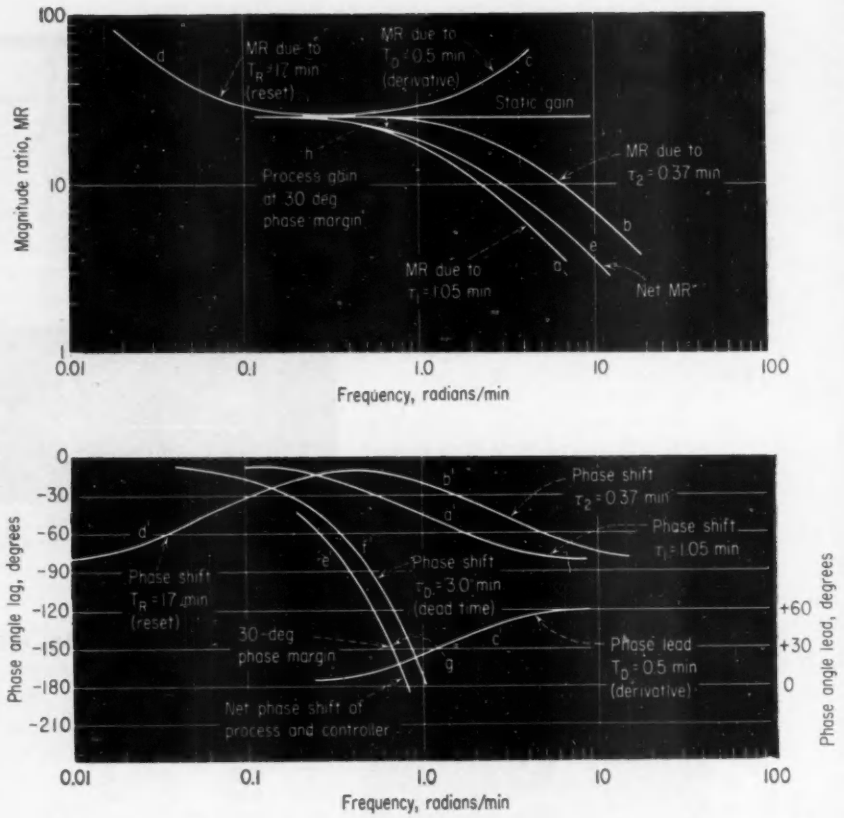

FIG. 4. Frequency response of side temperature vs. reflux flow.

Figure 4 contains the frequency-response contribution of each factor to the transfer function representing the dynamic process. Curves a and b are magnitude ratios of the two first-order lags, which represent the fractionating column and the temperature-measuring and transmission elements. These are plotted with a first-order lag frequency response template whose reference mark is placed at the radian frequency equal to the reciprocal of the time constant in minutes. At this "break frequency" a known relationship exists: the phase lag is 45 deg. The static gain of 25.3 is drawn as a horizontal straight line. The gain for the dead time is unity and need not be drawn.

The phase angle curves a' and b' for these two lags are drawn using phase angle templates. The dead time curve f' is drawn with a dead-time phase angle template referenced on the graph, with the radian frequency equivalent to the dead time of 3.0 min.

As a first approximation, the total phase shift of minus 150 deg (a 30-deg phase margin) due to the two time constants and the dead time is found, and the tentative gain crossover frequency at which this occurs, in this case 0.6 radians per min, is noted. This assumes the controller has proportional action only.

Then the reset template is adjusted to give less than minus 10 deg phase shift at the tentative gain crossover frequency. The magnitude and phase shift are curves d and d'. Since the phase shift of reset at one decade in frequency above its reference frequency is only minus 7 deg and since less than 10 deg is desired, the reset reference frequency can be set one decade below the tentative gain crossover frequency. This technique represents a simple and correct way of setting reset. In this case the reset frequency then is 0.6/10 or 0.06 radians per min. The reset time constant setting, as it appears on the controller, is the reciprocal of this value: $T_R = 1/0.06 \approx 17$ min

About 15 deg of phase lead is introduced at the tentative gain crossover frequency to provide the best rate action. Curves c and c' are drawn in, with the template reference frequency—the frequency of 45 deg phase lead—placed at about 2 radians per min to give 15 deg phase lead at 0.6 radians per min. The reset time T_D is the reciprocal of 2, or 0.5 min. (The subscript D stands for derivative, a synonymn for rate.)

The composite magnitude ratio curve e, including the process and controller, is obtained by adding the graphical distances algebraically from the static gain line of 25.3. This is equivalent, because of the logarithmic scale, to multiplying the individual magnitude ratios. The composite phase angle curve e' for the controller and process is obtained by adding algebraically all individual phase curves of the system.

The stability criterion calls for unity total loop gain at approximately 30 deg phase margin (minus 150 deg phase shift) after the reset and rate contributions have been added to the frequency response diagram. This margin is identified as point g (0.67 radians per min.) Tracing upward along this new gain crossover frequency, the process gain at 30 deg phase margin is found to be 20.8, point h on the composite magnitude ratio curve. For the total loop gain to be unity at this point, the controller gain must be set at the reciprocal gain of the process:

$$G_c' = 1/20.8$$

This must be converted to actual controller terms, either proportional band or gain. The controller range is 50 deg C (100 minus 50; see Figure 5) and the air pressure span is the standard 12 psi. The actual controller equivalent gain then is:

$$G_c = \frac{50}{12 \times 20.8} = 0.2 \text{ psi/psi}$$

The controller proportional band is the reciprocal of this gain, or

$$PB = \frac{1 \times 100}{0.2} = 500 \text{ percent}$$

The three necessary controller settings have been found. With some slight change in these settings during a secondary tuning operation—after putting the loop back on automatic control—the system will be sufficiently stable, as shown in Figure 5, to meet process objectives and permit the process to be operated without further manual supervision. Figure 5 also shows what happens when somewhat different settings are used from those calculated above.

frequency response is rapidly plotted. Worksheet II gives details of this plotting and the method of determining controller settings.

Setting the controller

The column is controllable. Analysis of the frequency-response diagram shows that the controller gain, for a stability criterion of 30-deg phase margin at the gain crossover frequency, is 0.20 psi/psi for stable control. The reset time is 17 min. The rate action setting of 0.5 min can improve control only slightly because of the dominating dead time in the process transfer function.

In dynamic analysis, the closed-loop time response of the process—the information actually desired about a system during its operation with normal disturbances—can be readily approximated from the open-loop frequency response diagrams. The oscillatory frequency of the closed-loop control system is approximately the frequency at the minus-180-deg phase shift of the open-loop system, which in this case is 0.107 cpm or 9.33 min/cycle. For a 30-deg phase margin—which the controller is now set for—at least two complete cycles (about 19 min) are needed for recovery from a set-point change. The time to recover from a load disturbance due to a feed composition change will be slightly more. This large recovery time is one of the reasons this control system resisted the trial-and-error approach to determining controller settings.

Verifying the settings

Some results of dynamic analysis are shown in an actual chart record, Figure 5. The record presents the response to a set-point change at predicted controller settings (left) and then at settings sufficiently different to produce a more oscillatory response. Two different set-points are shown for each group of settings. Had a trial-and-error technique been started at the first settings those at the right would have appeared to be a normal progression from the original settings. However, analysis reveals that even a small increase in controller gain (smaller proportional band) would make the system more oscillatory, with larger deviations from set-point. The record also shows how the system stability changes (i.e., the process gain differs) with each set-point due to the nonlinear temperature vs. tray number gradient through the column. With either group of controller settings, the system is more stable at the 82-deg lower process gain than at the higher gain at 83 deg.

Followup

Are process modifications necessary? It would be desirable to modify the process to eliminate the dead time—but this would be difficult since the major part of dead time results from the necessary fractionating requirement of material holdup on trays in the column. A small portion of the dead time is due to the distance between the temperature transmitter and the controller; but the temperature-measuring element must be located where it is because of the nature of the separation of monoglycol and water, and because it is desirable to have the detector in a region of the column sensitive to temperature changes. The process therefore was left as is.

Are controller modifications necessary? Rate action gives a little improvement in dynamic response, but not enough to pay on a new installation. Here, since it was already available, it was set at 0.5 min rather than being removed from the controller. The calculated value of reset is 17 min, but Figure 5 carries a final setting of 15 min. This modification occurred during a secondary tuning operation, after the controller was reconnected to automatic. Such secondary tuning may be necessary because the illustrated method of dynamic analysis, while rapid and simple, may be limited in accuracy by the numerous assumptions and shortcuts involved. In addition, adjustment-dial calibration is notoriously poor.

The fact that proportional band (controller gain) of 500 percent remained at this calculated value after secondary tuning was somewhat fortunate. Controller gain depends on process static gain, and in this case the static gain depended in turn on the validity of the assumption made about the final temperature after the step upset had been introduced.

SUGGESTED READING

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2. *HOW TO RECKON BASIC PROCESS DYNAMICS*, Leslie M. Zoss, "Control Engineering", Vol. 3, January 1956, pp. 50.
3. *HOW TO FIND CONTROLLER SETTINGS FROM PROCESS CHARACTERISTICS*, Geraldine A. Coon, "Control Engineering", Vol. 3, May 1956, pp. 66.
4. *HOW TO SET THREE-TERM CONTROLLERS*, Geraldine A. Coon, "Control Engineering", Vol. 3, June 1956, pp. 71.

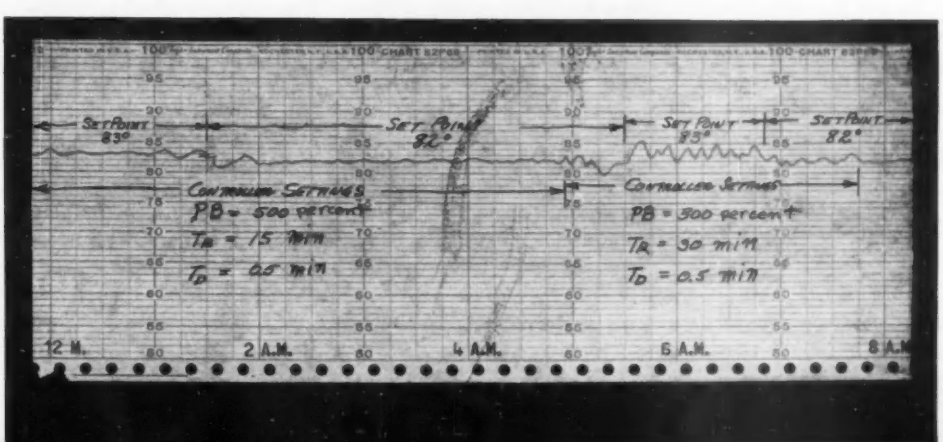


FIG. 5. Actual chart records obtained after secondary controller tuning of calculated settings, and a variation to show how system oscillates when controller is not set properly.

Applying Electromechanical Servo Actuators

THE GIST: As it goes up in power rating (10 watts and above), the conventional servomotor draws proportionately heavier control currents. Translated into terms of system hardware, this characteristic means that big, costly amplifiers are needed to provide sufficient power. A servo actuator, on the other hand, requires control currents only large enough to energize a clutch or brake, and hence can be supplied from smaller power supplies. The authors describe the operation of typical actuators, giving a detailed explanation of how gear ratios, power dissipation, and acceleration times can be determined.

EVERETT D. HODGE, Electomic Mechanisms, Inc.
SIDNEY DAVIS, Consulting Electrical Engineer

The electromechanical servo actuator, such as the "EMA" pictured in Figure 1, consists of drive motor, brakes, and gearing arranged in a compact package. It is designed to compete with the conventional servomotor for use as the drive element in medium-power, fast-response servomechanisms. The principal advantages of the actuator are high power output from a given frame size, low control-power requirements, and fast acceleration. A major limitation is inherent instability, which must be compensated for by the addition of stabilizing networks.

Servomotors are highly refined instruments in which good dynamic response rather than power efficiency is the main design goal. Their performance is unexcelled in systems requiring up to 10 watts of mechanical power. Above this level of output, the control power required for conventional servomotors becomes comparatively large, leading to a requirement for bulky and costly control amplifiers. The problem becomes critical in systems handling 25 and more watts of mechanical output—especially when two-phase ac servomotors are employed.

In actuator-driven systems, Figure 2, the control amplifier need supply only enough power to energize an electromagnetic clutch or brake. In fact, there is little relationship between control power and mechanical power output. By efficient brake design it is possible to control large outputs with only a few milliwatts from the amplifier. The motors used in actuators are constant-speed, high-torque units that run continuously even when no output is needed. They can, therefore, produce approximately four times the shaft output of a conventional servomotor in the same frame size.

The actuator incorporates gearing to provide the necessary match of drive motor to load. By the very nature of the mechanical design there is no backlash to affect the output shaft. This is a matter of the greatest importance in the stabilization of high performance servomechanisms, especially in the high power range where spring-loaded gearing (the usual remedy for backlash) is unsuitable.

In the simplified unidirectional servo actuator of Figure 3, a motor operates through a mechanical differential to drive a load. An electric brake on the third shaft of the differential is controlled from a dc source. With no current in the brake coil, the drive motor rotates at full speed but the load remains stationary. When, on the other hand, a large control current is applied, the brake locks and full motor power is transmitted to the load. Between these two extremes the torque applied to the load can be varied in an infinite number of steps. The greater the current in the brake coil, the less the brake will slip and the faster will be the load speed.

To analyze the behavior of this simple system, it is commonly assumed that the drive motor has sufficient inertia and capacity so that its speed is not significantly affected by fluctuations in the load. It is also assumed that the friction torque developed at the brake is independent of speed and proportional only to control current. This, however, holds only as long as some slipping occurs in the brake. When the brake is locked, its no-slip torque is determined by the characteristics of the load.

The circuit of Figure 4 is equivalent to the mechanical system of Figure 3 and forms a convenient basis for analysis. It is especially valuable in the solu-

FIG. 1. Typical bidirectional servo actuator. This unit is the "Electro-Mechanical Amplifier" made by Electomic Mechanisms, Inc.

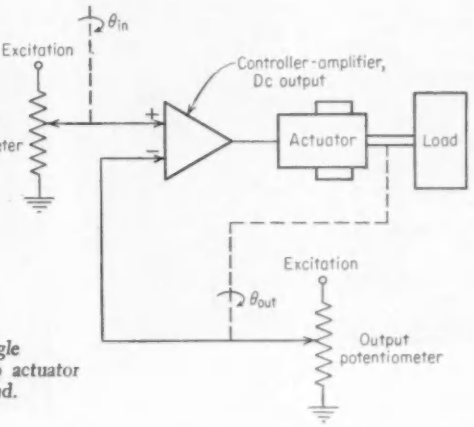


FIG. 2. Potentiometer-type angle transmission system using servo actuator to position a relatively heavy load.

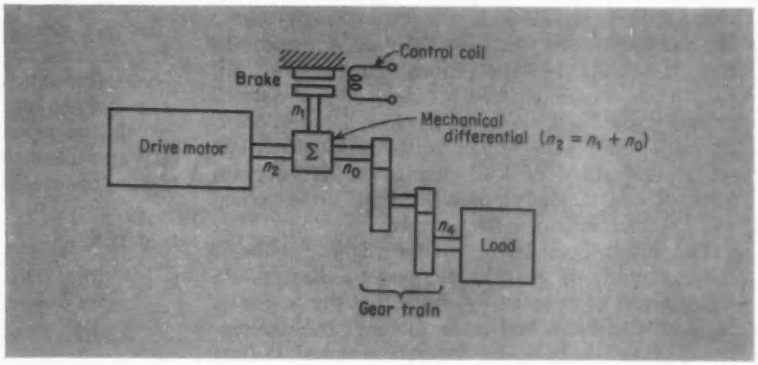


FIG. 3. In simplified unidirectional actuator, n_0 through n_4 represent relative shaft speeds at various points in the system.

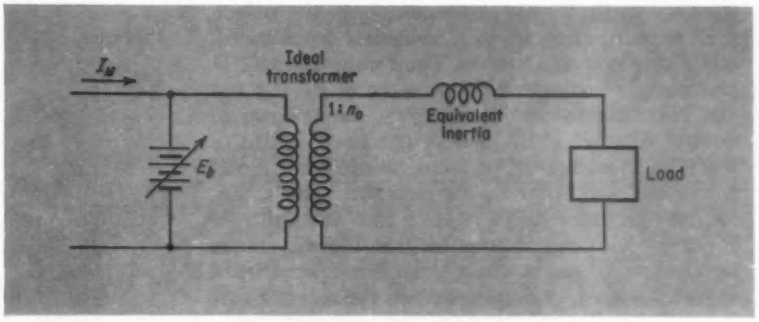


FIG. 4. Equivalent circuit for unidirectional actuator.

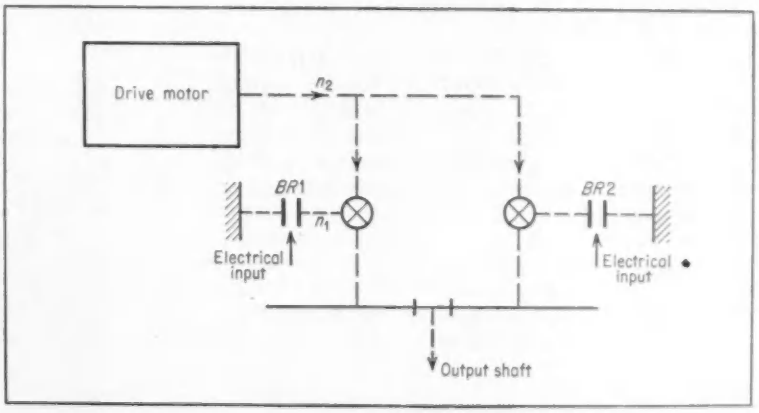


FIG. 5. Schematic diagram for bidirectional actuator.

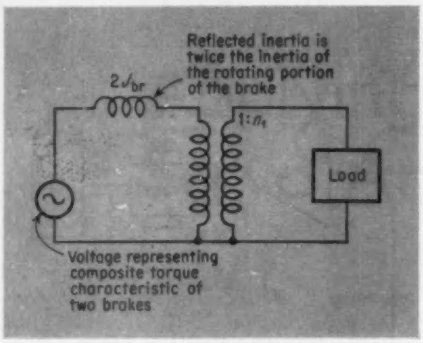

Reflected inertia is twice the inertia of the rotating portion of the brake
$2J_{br}$
$1:n_1$
Load
Voltage representing composite torque characteristic of two brakes

FIG. 6. Equivalent circuit for bidirectional actuator applies only when brakes are slipping.

tion of numerical problems, such as that depicted in the accompanying design problem involving a unidirectional servo actuator. Although the techniques involved use only the elementary principles of mechanics, they provide a clear picture of performance for the system designer. He will find, for example, from the solution of this problem that only a small part of the power required for the load is dissipated as heat in the brake. As a result, rather large amounts of load power may be controlled efficiently. The actual magnitude of load permissible for a given actuator size depends upon the duty cycle, which will be discussed in a later section.

The bidirectional servo actuator, Figure 5, consists fundamentally of drive motor, two mechanical differentials and two brakes. Assume that the gear ratio between the motor and brake shafts of the differential is n_1 and that the output shaft is locked. When the control coil of *BR* 1 is energized, this brake develops a slip torque in proportion to the magnitude of control current. And, since it is de-energized, *BR* 2 develops zero torque. The torque available at the load shaft equals the slip torque of *BR* 1 times the gear ratio n_1 and is, therefore, proportional to control current. If *BR* 2 were energized in lieu of *BR* 1, an equal amount of torque would be delivered to the load, but in the reverse direction. The reasoning may be extended to running conditions in conformance with the assumption that the slip torque developed by the energized brake is independent of speed. Thus, when slipping occurs, the actuator may be considered to exhibit the idealized speed-torque characteristics shown in Figure 7 for various brake control currents.

In the case of zero slip, the output shaft rotates uniformly and independently of control current. This independent or nonlinear behavior of the actuator must be studied as a separate mode of operation. However, by isolating the nonlinear portions of the problem, analysis is still possible and, in fact, can be made quite simple.

Dynamic characteristics

It can be seen from Figure 6 that dynamic lags stem from two principal sources: electrical time delay in the brake control coil, and mechanical time delay from system inertia. As a result of magnetic saturation, the time delay in the control coil is actually a nonlinear function of signal amplitude. However, it may be assumed to be a simple linear delay (as an adequate first approximation), and may be minimized by careful design of the control circuit.

If drive-motor speed is constant, the effective system inertia corresponds to the inertia of the rotating member of the brake (neglecting the inertia of the gearing). In bidirectional actuators, of course, both brakes contribute equally to system inertia. The effective inertia at the load shaft is determined by multiplying actuator inertia by the square of the gear ratio. The fact that this reflected inertia is lower than that for a comparable servomotor partially accounts for the faster accelerations achieved by actuator use.

Since brake torque is proportional to control current and independent of speed, load torque (brake torque times n_1) is also independent of speed. Similarly, acceleration can be shown to be unaffected by speed in the case of a pure inertia load. The benefits of this independence become evident when the actuator characteristics in Figure 7 are compared with the speed-torque curves for a conventional

FIG. 7. Speed-torque characteristics of ideal actuator for uniformly spaced values of control current.

FIG. 8. Ideal speed-torque curves for a conventional servomotor.

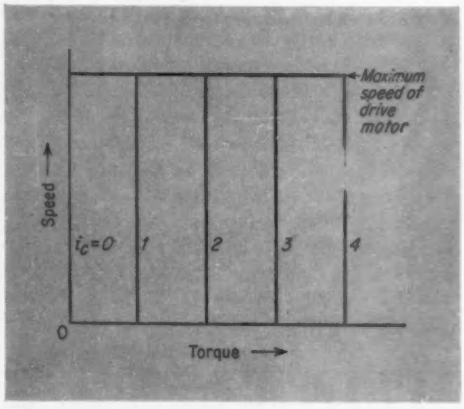


FIG. 7

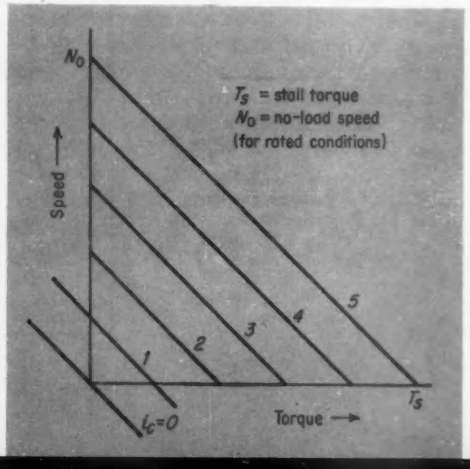


FIG. 8

How to Calculate Actuator Characteristics

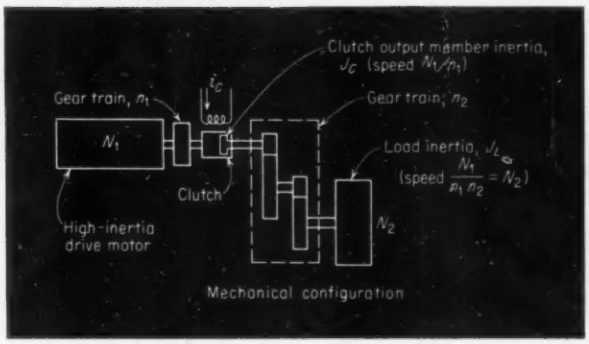


FIG. A

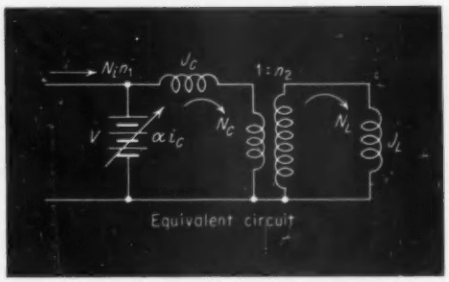


FIG. B

PROBLEM

A unidirectional servo actuator is to be used to drive a memory drum in a digital computing device. The mechanical configuration and the known system parameters are shown in the accompanying sketch. The input to output velocity ratios for the two gear trains are designated as n_1 and n_2. Gear inertia and load friction are assumed negligible. Determine:

1. The gear ratios required for maximum acceleration of the load from rest to full speed.
2. The average horsepower delivered to the load during the period of acceleration.
3. The acceleration time.
4. The total energy dissipated in the clutch during acceleration.
5. The steady-state dissipation in the clutch.

SOLUTION

1. The first step in the solution is to draw the equivalent circuit. Clutch torque is represented as an adjustable battery voltage V driving currents N_e and N_L (representing clutch and load speeds) through the inductances J_e and J_L, which simulate the system inertia. The drive motor is assumed to have constant speed, N_1. Accordingly the input member of the clutch rotates at N_1/n_1. Battery voltage (brake torque) determines system response.

The circuit drawn applies to all operating conditions except that of steady zero-slip. It may be simplified by Thevenin's Theorem to eliminate the input mesh current N_1/n_1. For maximum load acceleration the ratio n_2 must be optimized. To do this, the designer writes the system equations:

$$V = J_e \frac{dN_e}{dt} + \frac{1}{n_2^2} J_L \frac{dN_e}{dt}$$

and

$$A_L = \frac{1}{n_2} \frac{dN_e}{dt}$$

where A_L = load acceleration.
Therefore

$$V = \left[J_e + \frac{J_L}{n_2^2} \right] n_2 \times A_L$$

It is necessary now to solve for A_L, then differentiate with respect to n_2.

$$\frac{dA_L}{dn_2} = \frac{-V \left[J_e - \frac{J_L}{n_2^2} \right]}{\left[J_e + \frac{J_L}{n_2^2} \right] \times n_2}$$

To optimize, let $\frac{dA_L}{dn_2} = 0$

Then

$$J_e = \frac{J_L}{n_2^2} \text{ and } n_2 = \sqrt{\frac{J_L}{J_e}}$$

The latter is the optimum gear ratio for the conditions of the problem. The value of maximum acceleration using this optimum ratio is

$$A_L = \frac{V}{2 J_e n_2}$$

which is precisely one-half the acceleration of the clutch output member when this member is running light.

It is possible now to determine the remaining gear ratio n_1. Since the required load speed is N_L, the speed at the output end of the clutch may be written as

$$N_e = N_L \sqrt{\frac{J_L}{J_e}}$$

This equation is then equated to N_m/n_1, the drive motor speed reflected through the first gear train. Solution of the resulting equation yields the value of n_1.

2. The average horsepower delivered to the load during acceleration is readily determined. Since torque is constant, the load acceleration is also uniform, thus effecting a linear increase in speed with time. Average power equals torque times average speed, or:

$$HP_{av} = \frac{N_2}{2} \times T \times \frac{1}{1.009}$$

$$= \frac{1}{2.018} N_2 T$$

where N_2 is in rpm, T in oz.-in.

3. Acceleration time is simply the ratio of final load speed to load acceleration:

$$\text{time} = \frac{N_2}{A_L}$$

4. The energy dissipated in the clutch at any instant equals the product of instantaneous torque and slip speed. The instantaneous clutch power must equal the instantaneous load power during the acceleration period, since reflected torques and speeds are equal. Thus, the total clutch dissipation during acceleration equals the rotational kinetic energy imparted to the inertial load:

$$KE = \tfrac{1}{2} J_L N_2^2$$

The clutch must have sufficient thermal capacity to absorb the heat equivalent of this energy without damage. This is particularly important when the duty cycle calls for repeated acceleration periods interrupted only by brief intervals wherein cooling can take place.

5. The steady state power dissipation in the clutch is zero (theoretically), since negligible load dissipation requires negligible power to maintain speed. Actually losses in gearing and bearings do occur.

servomotor, Figure 8. The performance of the conventional motor is considerably affected by the reduction in available output torque with increasing speed for fixed values of control current. With zero control current, for example, no torque exists at standstill. Yet if the shaft is given a spin a negative torque opposing rotation is developed. This opposing torque does not exist in an actuator. Further, under steady load conditions, servomotor velocity is proportional to control signal, while in an actuator acceleration is proportional to control signal. The significance of this difference can be demonstrated by attaching a viscous damper to the shaft of the actuator. The effect of this damper would be to subtract a torque

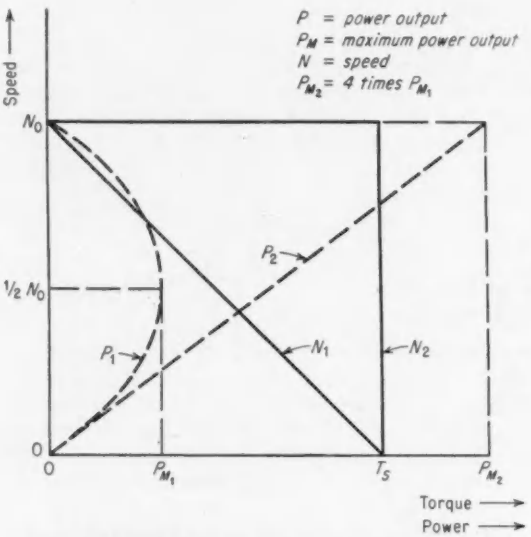


FIG. 9. Comparative performance characteristics for a conventional servomotor (subscript 1) and an electromechanical servo actuator (subscript 2). At any speed, power output is the product of torque and speed.

proportional to speed from available shaft torque. A test run under these conditions would yield a family of curves similar to those of Figure 8.

The speed-torque characteristics of the actuator may thus be regarded as those of a conventional motor without viscous damping. This tends to prove that the actuator is a more efficient drive since it does not have the friction losses inherent in the viscous damper. The mechanical power outputs of actuators and servomotors are compared in Figure 9. Another advantage of the absence of viscous damping is that servomechanisms incorporating the actuator are not troubled by a velocity error proportional to speed. This factor plus the low inertia and small electrical time delays of the actuator make it suitable for highly accurate fast-response systems.

Although viscous damping introduces inefficiency and error it does help stabilize closed-loop systems. The lack of inherent damping becomes a detriment, therefore, when applying the actuator to closed-loop controls and stabilization must be externally provided. The techniques for accomplishing this are based on use of familiar lead networks or tachometer damping.

As in all systems, load characteristics exert a substantial effect on system dynamics. For the case of an inertia load, maximum load acceleration is achieved when gear reduction n_1 is chosen to equate effective brake inertia and reflected load inertia. The effect of load friction depends on the nature of such friction. Viscous friction (proportional to speed) provides system damping; coulomb friction (independent of speed) merely reduces available torque. Static inaccuracy due to coulomb friction occurs, as in conventional positioning servomechanisms, depending on the ratio of friction torque to stiffness (torque per degree of deflection) of the load shaft.

Response to various inputs

A description of the simple control system application of Figure 2 will aid further in visualizing the behavior of the servo actuator. It is assumed that the controller or preamplifier is designed to produce excitation that varies linearly with error signal amplitude and that is applied to an appropriate brake coil as determined by the signal polarity. The problem is to use physical reasoning to determine the response to different inputs, including step functions, constant velocity signals, and sinusoidal signals.

The visualization process may be materially simplified by considering the equivalent electrical circuit in Figure 6. Here, the constant-speed drive motor is simulated by a constant-current source.

Figure 10 shows the response patterns for different kinds of load and operating conditions when a step voltage is applied to BR 1 while BR 2 remains unenergized. Initially, there is a delay due to the build-up of brake torque. Note, too, that the transients end abruptly when steady-state speed is reached, after which no further speed increase is possible.

With a constant-velocity input, the speed of the brake is precisely defined. Its actual value depends on load speed by virtue of the fact that the sum of brake speed plus load speed (properly adjusted for gear ratio) must equal the constant drive-motor speed. Under constant-velocity conditions, the brake slips continuously, causing the generation of heat. The slower the load speed, the faster will the brake slip. Since the proportionality of brake and load torques is determined only by the gear ratio, the following formula may be written for the relative power dissipation in load and brake.

$$\frac{P_{load}}{P_{brake}} = \frac{1 - S}{S}$$

where P_{load} = load driving power
P_{brake} = brake dissipation
S = brake slip speed as a fraction of maximum speed

The greatest dissipation in the brake occurs when a high-friction load is driven at a low speed relative to the maximum slew speed of the actuator. On the other hand, an inertia load requiring zero constant-velocity torque, represents negligible loading.

It is more difficult to find the response to a sinusoidal input. One approach is to make the simplifying assumption that brake torque rather than brake current or voltage constitutes the sinusoidal input. As a matter of fact, brake torque does follow the coil current very closely. For a pure inertia load, the instantaneous acceleration is proportional to torque and, therefore, tracks a pattern that is sinusoidal but displaced from the input by 180 deg—a phase reversal characteristic of systems of this nature. The principal obstructions to perfect sinusoidal response are the nonlinearities inherent in servo actuators for certain types of inputs. For large amplitude, rapidly changing signals, where the speeds available in the system tend to be exceeded, distortion occurs because of the limiting velocity of the system.

Control circuits

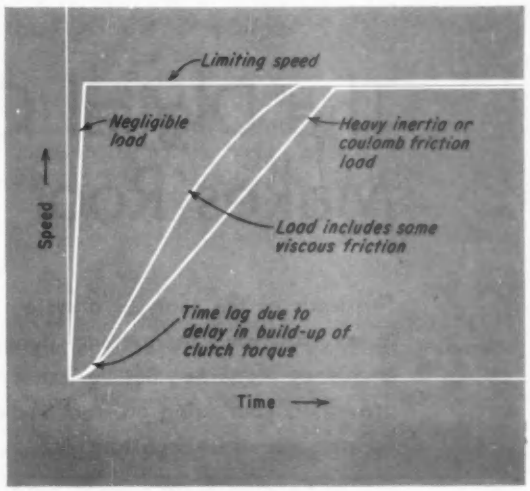
Up to this point, bidirectional actuators have been assumed to possess brakes of ideal characteristics, and to consist merely of two independent unidirectional sections, only one of which is actuated at a time. Actually, the designer will find that these idealizations are not entirely true—a fact that, fortunately, can be compensated for in the control circuit.

The behavior of a magnetic brake is a function of the ampere-turns of magnetomotive force effective in producing flux. Thus, a true plot of brake characteristics should show torque vs. ampere-turns rather than torque vs. current. In general, however, there is a fixed volume of space available for the magnetizing coil in a specific brake design. Since the weight of copper that can be contained within that space is thus approximately fixed, the torque vs. current relationship is valid for circuit design.

In the typical brake torque vs. control current characteristic of Figure 11, nonlinearity is noted in two parts: the initial region of low control current, and the region of saturation. The former is of principal interest for normal control operation and indicates a reduction in sensitiivty to small signals. Fortunately, such nonlinearity can be completely cancelled by push-pull input circuit design.

Time-constant correction is based on the assumption that the coil magnetic circuit is linear and has a time constant of L/R. The solution, therefore, is to reduce this time constant by one of the many techniques available. A simple remedy is the insertion of a series resistor, but unfortunately this correction increases the control power requirement by exactly the same proportion as the reduction in time constant. Alternative means of time constant reduction include energization from tubes having essentially constant current output (for fixed grid signals) such as pentodes, or from circuits achieving the same results by current feedback.

In addition to time-constant correction, the servo actuator usually requires some type of stabilization network. The need for this can be understood by inspection of the frequency response characteristics of the actuator. A Nyquist plot of even the simplest actuator reveals that the response curve passes through the minus 1 point—definitely indicating instability. This condition is aggravated by any additional time delays in the system, such as that due to the brake control-coil inductance.



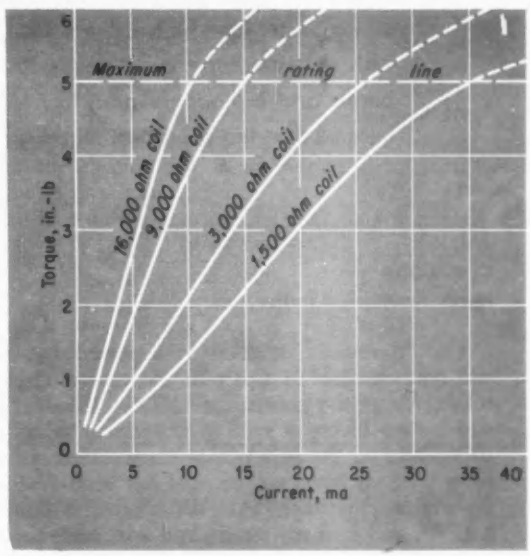


FIG. 10. Actuator response to step inputs for various loads.
FIG. 11. Typical torque-control current relationships.

The Digital Computer Makes Root Locus Easy

The locus of the roots of a system's characteristic equation is a great aid to understanding the system's dynamic behavior and improving its transient or frequency response. But the amount of calculation necessary may well have prevented your using the root locus method except for the simplest systems. To preserve this important link between transient response and frequency response, three programs have been written for the IBM 704 electronic digital computer. These programs will produce the complete locus of roots in a minute or two with very high accuracies. They will generate the closed-loop root locus with its associated gain points for systems up to the 30th order, or the phase and orthogonal gain loci for simpler systems. Flow charts are included here so that the programs might be adapted to other computers besides the 704.

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The "root-locus" method[1] is a powerful analysis and synthesis tool that permits the control engineer to observe, at the same time, both the transient and steady-state effects of specific component values and parameters on the behavior of complicated systems. How the root locus can be used has been described in several important texts on control system design[1,2,3], and in many papers and articles[4,5], and the great utility of the method is generally conceded.

The most important deterrent to its practical application has been the long, tedious calculations which have to be performed to obtain the locus of roots for even the relatively simple systems. Digital computer programs have therefore been written to find the root and gain loci of systems up to the 30th order, and also, the phase angle and associated orthogonal gain loci.

The basic problem in obtaining a root locus is that of solving an equation in the form of a sum of two polynomials in s for its roots. In general, the equation has the form:

$$A_n' s^n + A_{n-1}' s + \ldots + A_1' s + A_o + K' (B_m' s^m + B'_{m-1} s^{m-1} + \cdots + B'_1 s + B_o) = 0$$

in which the A terms represent the poles (denominator) and the B terms the zeros (numerator) of the open-loop transfer function of the closed-loop system under study. This equation is called the "characteristic equation" for the system, and its roots are the poles of the closed-loop system. (The zeros of the closed-loop system are the zeros of the forward function and the poles of the feedback function.

Preferably A_o and B_o should be reduced to unity by dividing each term of the equation by A_o and factoring B_o out of the B terms, so that the coefficient K' is modified to $K=K'\ (B_o/A_o)$. In this form there is no gain associated with either of the two polynomials, and the gain K represents the actual steady-state open-loop gain of the system.

The equation can then be reduced to a single polynomial by combining terms in like order of s. For example, if $m=n-2$, and $A_o=B_o=1$, the characteristic equation is

$$A_n s^n + A_{n-1} s^{n-1} + (A_{n-2} + KB_m) s^{n-2} + (A_{n-3} + KB_{m-1}) s^{n-3} + \cdots + (A_2 + KB_2) s^2 + (A_1 + KB_1) s + (1 + K) = 0$$

This equation must then be solved for each gain K for which the points on the locus of roots are desired. Three programs have been written to solve this problem by machine. The first and simplest produces the 180-deg (closed-loop) locus of roots with the associated gain points for systems up to the 30th order. The second program produces the locus of roots for an angle interval $180/n$ deg (n is an integer), so that constant-gain and phase contours can be added to the plot of root loci. The third program is similar to the second, but more complicated: it includes steps to automatically rescale the polynomials whenever they exceed the limitations of the computer.

Each of the programs must naturally include limits for starting and stopping the calculations, as well

as the amounts by which succeeding values of the gain and phase are to be incremented in calculating the various loci. But the basic step is a program for extracting the roots of a polynomial. Several such programs were found to be available to SHARE users of the IBM 704 computer, and these were scanned for the one most applicable to the root-locus problem. The one finally used as the root-extraction subprogram in the automatic root and gain locus program is SHARE No. CL AEQ 1.

Root and gain locus program

The simplest program calculates the root and gain locus for the normal, closed-loop, 180-deg phase contour only. It requires (flow chart, Table II) that input data be stored in the computer as in Table I. This program has the following features:

1. The locus can be started with any specified gain and can be stopped at a specified gain.
2. The locus can be stopped at the $j\omega$ axis.
3. The locus can be stopped at a specified gain in the unstable region.
4. The number of locus points desired in a given region can be specified for three separate regions of the root locus, or by iteration to any greater number of regions for any single machine computation.
5. The amount of detail in any region can be specified by choosing either a small or large number for the incremental gain in that region.
6. If the poles of the characteristic equation are not explicitly known, they can be obtained with other data concerning the root locus by starting with a gain of zero. Because of the economy of the entire procedure it is recommended that all root and gain loci problems be started with initial gain of zero to automatically check the location of the poles.
7. If the zeros of the characteristic equation are not explicitly known, they can be obtained automatically by inserting data for this computation.
8. Roots or closed-loop poles for specific gain of interest can be obtained: a) as the first set of roots by choosing K_o as that gain; b) by choosing the incrementing unit and the number of increments so that the specific gain K is formed as an intermediate or final value.
9. Results are obtained as tabulated data and can

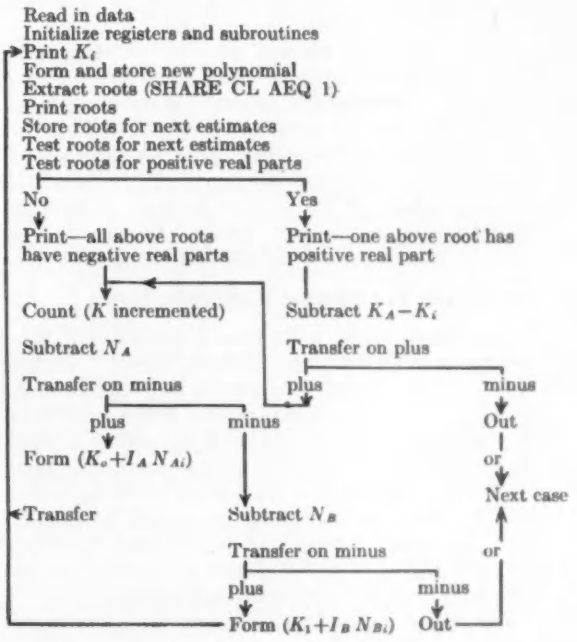
TABLE I

DATA REQUIRED FOR ROOT AND GAIN LOCUS PROGRAM

Storage Locations (IBM 704)	Description	Octal Point (Fixed)	Octal Point (Floating)
D to D + 30	Coefficients of polynomial N of poles — constant term first		X
D + 31 to D + 61	Coefficients of polynomial M of zeroes — constant term first		X
D + 62	K_o, initial gain (start of root locus)		X
D + 63	K_A, limiting gain (secondary stop for iteration)		X
D + 64	I_A, first increment to gain		X
D + 65	I_B, second increment to gain		X
D + 67	N_A, number of times first increment is used	X	
D + 68	N_B, number of times second increment is used	X	
D + 69 to D + 128	J, trial roots if any (complex form)		X
D + 130	*Zero* for real coefficients *one* for complex coefficients (not used for root locus)		X
D + 131	S, one to seven, usually four (number of octal places of accuracy)	X	
D + 132	N, order of polynomial N	X	
D + 133	M, order of polynomial M	X	
D + 134	I_C, third increment to gain		X
D + 135	N_C, number of times third increment is used	X	

TABLE II

FLOW CHART FOR ROOT AND GAIN LOCUS PROGRAM



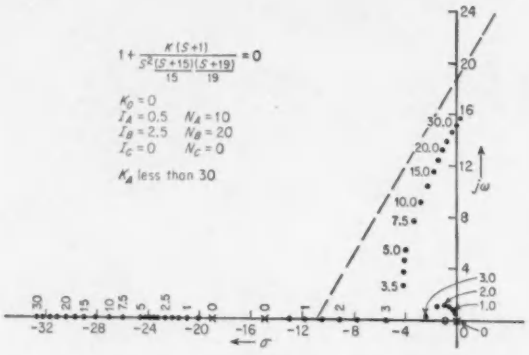


FIG. 1. Root locus plot for values of K incremented as shown, starting from K = 0. All points computed are plotted. Note need for more detail between K = 3 and K = 3.5.

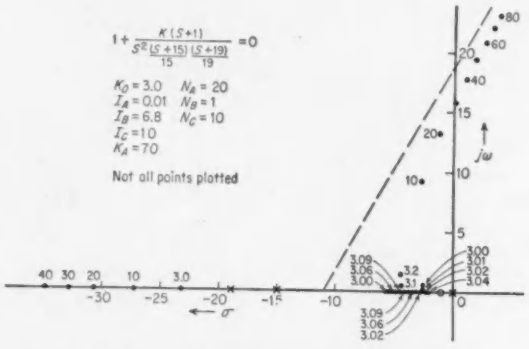


FIG. 2. Root locus plot of same equation as Figure 1, with much smaller increments in K used to obtain accurate curve at break-away point.

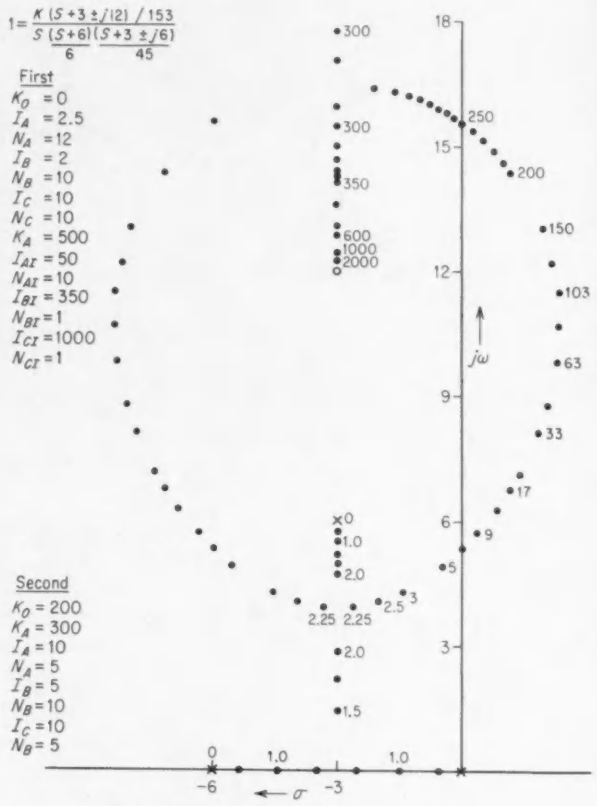


FIG. 3. Root locus plot of digital computer results shows how second computation was used to fill in precise location of locus between K = 200 and K = 350.

be plotted by clerical help rather than by engineers, or, if automatic plotting equipment is available, plotted automatically.

10. The data is tabulated showing the gain, the associated set of roots or closed-loop poles, and a statement as to whether an unstable root is present.

11. An estimate of machine time required can be obtained from the following figures. A system with a characteristic equation represented by 10 poles and five zeros required 2.6 min to obtain a locus with 35 ten-point sets of gain points. Another system with a characteristic equation represented by four poles and two zeros required 1.72 min to obtain a locus of 46 four-point sets of gain points.

12. Accuracy of the root and gain locus is very high. It is particularly evident and appreciated in the regions where two loci lie close to each other.

Figures 1, 2, and 3 illustrate how the detail can be improved in any area of the locus by decreasing *I*, the increment of *K* used. Note that the data term *J*, stored at $D+69$ to $D+128$ (Table I) is associated with roots of a polynomial with complex coefficients. This term is zero for root locus calculations, since all coefficients must be real.

Program for phase and gain loci

Phase angle loci, with their corresponding gain points, usually are not calculated when the root locus method is used, because the long and arduous calculations for the normal 180-deg locus must then be multiplied by the number of phase loci desired. The speed and accuracy of digital computers now make these calculations feasible. The data yielded by the phase loci and their associated orthogonal gain loci makes the calculation of these loci very much worthwhile—if the digital computer is to be used to generate the normal root loci.

The digital method for obtaining the phase angle loci is related directly to the automatic method for obtaining the 180-deg angle locus or normal "root and gain locus". Before proceeding with the method for obtaining the phase angle loci, consider the basic concept that the root and gain locus consists of a series of points which when substituted into the open-loop transform of a system gives a numerical value of −1; or an angle value of minus 180 deg. If the effect of each pole and each zero of the open-loop transform is doubled, the plot of points which had been the 180-deg angle locus now becomes a 360-deg angle locus, and what would have been a

90-deg angle locus becomes now the 180-deg angle locus. Going one step further and considering a triple effect, the 180-deg angle locus now is a 540-deg angle locus, and what would have been a 60-deg angle locus is now a 180-deg angle locus.

Note that the doubling or tripling of the effect of each pole and zero of the original transform is represented by raising the transform to the second or third power, respectively, and a new angle locus is determined by solving for the roots of the equation formed with the new transform.

A second concept can aid in obtaining a phase angle locus. Using a negative gain in the open-loop transform yields the 0-deg and 360-deg angle loci in place of the original 180-deg angle locus. Thus, by the two concepts of raising the open-loop transform to higher powers and using negative as well as positive gains, any angle loci can be generated.

As an example, for the 20-deg angle interval locus the original open-loop transform is raised to the ninth power. The 180-deg locus or in general, the $(2n+1)$ 180-deg locus of the new transform is the $(2n+1)$ 20-deg locus of the original transform, where $(2n+1)$ is an odd integer. By using the gain in a negative sense the 0-deg and 360-deg locus, or in general, the $(2n)$180-deg locus of the new transform is obtained. In relation to the original transform this corresponds to the $(2n)$20-deg angle locus where $(2n)$ is an even integer. Phase angle loci to any small angle interval can be obtained, provided that the interval corresponds to 180 deg/n where n is an integer, and that a root extraction subroutine of sufficiently high order is available.

Data required

A program useful for both the 180-deg angle locus and other angle loci is outlined in Table III. The data which must be read in consists of:

a. The coefficients of the polynomial representing the poles of the characteristic equation.
b. The coefficients of the polynomial representing the zeros of the characteristic equation.
c. The order of each of these polynomials.
d. The order to which the open-loop transform is to be raised determined by the angle loci desired. As n increases, so does angle loci information.
e. A logical number representing a choice of geometric or arithmetic progression for the gain.
f. Five incrementing numbers for the gain and five numbers representing the number of times each increment is to be used. Note that no limitation is placed on the form of the two polynomials representing the poles and zeros of the open-loop transform, since the machine program "normalizes" these polynomials.

It is important that the machine program give the angle loci for the angle 180 deg/n where n is only the final value of n, not all values from 1 to n. As n increases, so does angle loci information.

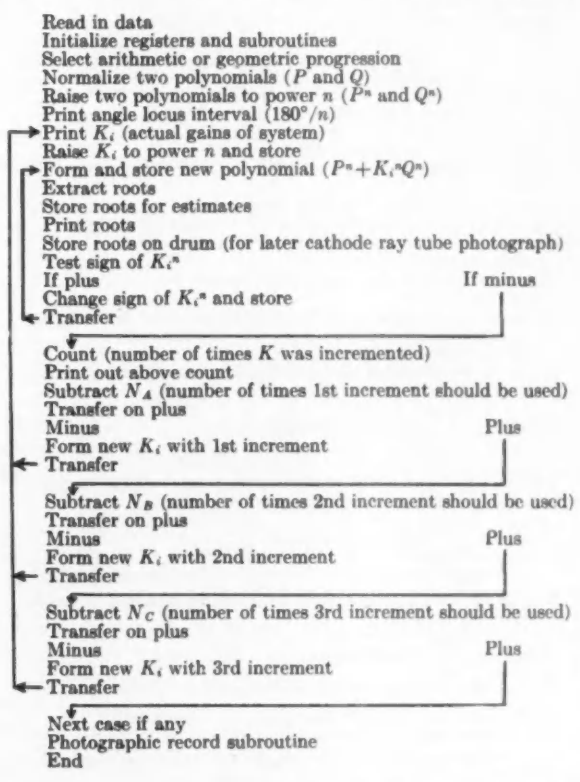
Features of the program

The phase-angle locus program includes all the features of the root and gain locus program, plus:

1. Selection of geometric or arithmetic progression for incrementing gain, although generally the geometric progression will be better.
2. A subroutine for a photographic display of a portion of the field. This makes a large amount of data available for plotting.
3. The orthogonal system of gain contours can be observed or further sketched in by interconnecting points of equal gain, already available.
4. Limited only by the capability of the root extraction subroutine, phase angle loci for small intervals of angle can be automatically computed and automatically plotted. Programs and subroutines for the IBM 704 digital computer for extracting roots of polynomials up to the 97th order have been published. This means that a 10-deg angle-interval locus is possible for a fifth-order system, a 20-deg locus for a 10th-order system.

TABLE III

FLOW CHART FOR PHASE AND GAIN LOCUS PROGRAM


Read in data
Initialize registers and subroutines
Select arithmetic or geometric progression
Normalize two polynomials (P and Q)
Raise two polynomials to power n (P^n and Q^n)
Print angle locus interval ($180°/n$)
Print K_i (actual gains of system)
Raise K_i to power n and store
Form and store new polynomial ($P^n+K_i{}^nQ^n$)
Extract roots
Store roots for estimates
Print roots
Store roots on drum (for later cathode ray tube photograph)
Test sign of $K_i{}^n$
If plus
If minus
Change sign of $K_i{}^n$ and store
Transfer
Count (number of times K was incremented)
Print out above count
Subtract N_A (number of times 1st increment should be used)
Transfer on plus
Minus
Plus
Form new K_i with 1st increment
Transfer
Subtract N_B (number of times 2nd increment should be used)
Transfer on plus
Minus
Plus
Form new K_i with 2nd increment
Transfer
Subtract N_C (number of times 3rd increment should be used)
Transfer on plus
Minus
Plus
Form new K_i with 3rd increment
Transfer
Next case if any
Photographic record subroutine
End

General program includes scaling

Raising the polynomials to a high order may produce coefficients for the new polynomials which will exceed the capacity of the digital machine. In this respect the limitation of the IBM 704 automatic digital computer is that the numbers must be less than 10^{35} or greater than 10^{-35}. This is not serious.

TABLE IV
FLOW CHART FOR ROOT AND GAIN LOCUS PROGRAM WITH AUTOMATIC SCALING

Read in data
Initialize registers and subroutines
Select arithmetic or geometric progression
Form and store B_o/A_o to adjust gains K
Form $K_m-(B_o/A_o)$ K with largest gain K
Form $P^i+K_m{}^iQ^i$ $i=1$ to n through loop
Test for overflow or underflow at each step of loop
Yes — No
Rescale coefficients so that largest coefficient equals reciprocal of smallest coefficient
Save multiplying factor for modifying gain K
Test i is less than n
Yes — No
Rescale polynomials P and Q by substitution of $S_1 = S/10$ and multiply K_m by 10^{M-N} where M is order of polynomial Q and N is order of polynomial P
Save gain multiplying factor 10^{M-N}
Save root multiplying factor $10 = b$
Rescale coefficients so that largest coefficient equals reciprocal of smallest coefficient.
Store polynomials P^n and Q^n
Store gain multiplying factor "a" developed above
Print angle locus interval $180°/n$
Print—Next (evaluated number) roots are associated with gain K_j (evaluate)
Raise K_j to power n and multiply by gain factor "a"
Form and store new polynomial $(P^n+a\,K_j{}^nQ^n)$
Extract roots (using stored root estimates)
Store roots for next estimates
Multiply above roots by root scale factor "b"
Print roots
Store roots on drum (for later cathode ray tube photograph)
Form and store new polynomial $(P^n-a\,K_j{}^nQ^n)$
Extract roots (using stored root estimates)
Store roots for next estimates
Multiply above roots by root scale factor "b"
Print roots
Store roots on drum (for later cathode ray tube photograph)
Count (number of times gain K_j was incremented)
Print out above number
Subtract N_A (number of times 1st increment should be used)
Transfer on plus
Minus — Plus
Form new K_j with 1st increment
Transfer
Subtract N_B (number of times 2nd increment should be used)
Transfer on plus
Minus — Plus
Form new K_j with 2nd increment
Transfer
Subtract N_C (number of times 3rd increment should be used)
Transfer on plus
Minus — Plus
Form new K_j with 3rd increment
Transfer
Next case if any or to photographic record subroutine
End of data analysis subroutine

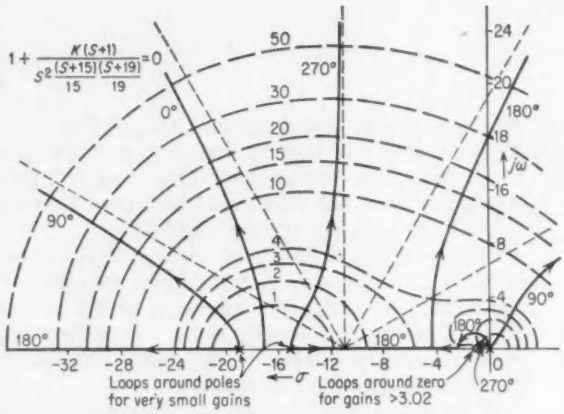


FIG. 4. Phase loci and orthogonal gain loci for same system plotted in Figures 1 and 2 for 90-deg increments in phase.

A general program, including scaling techniques, is outlined in Table IV. The first step in scaling the problem to the machine is to multiply the polynomials by a constant such that the largest coefficient is a reciprocal of the smallest coefficient in the combined expression (polynomial P plus K times polynomial $Q=0$, where K is the maximum gain to be used in obtaining loci and is properly adjusted for changes of coefficients of polynomials P and Q). In changing $P+KQ=0$ to $P^n+K^nQ^n=0$, this testing and readjusting of coefficients is done as each successively higher power expression is formed, until the nth power is reached. This requires n tests and n readjustments. If at any step the capacity of the digital computer is exceeded by a large or small coefficient regardless of the readjustment by a coefficient, then the equation must be rescaled. A substitution of the type $S=10S_1$ is made to rescale the equation, and again the equation is adjusted so that the largest coefficient is a reciprocal of the smallest coefficient. The raising of the transform to the nth power is then continued.

For each power n the gain is varied and the phase angle loci calculated. In all of these operations the numbers which represent the gain must be properly related automatically to the physical gains of the system, and the calculated roots related to the roots of the physical system.

Figure 4 illustrates the phase and gain loci calculated by the 704 computer for the system of Figures 1 and 2, for a 90-deg angle-interval locus.

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Custom-Designing Controllers for Time-Based Routines—II

Automatic operations that are sequenced on the basis of time often require special controllers, which can range in complexity from synchronous timers to full-fledged subsystems. All such controls can be described on a "Total Block Diagram", offered here as a tool to help determine beforehand which of the innumerable design approaches is best for a given application.

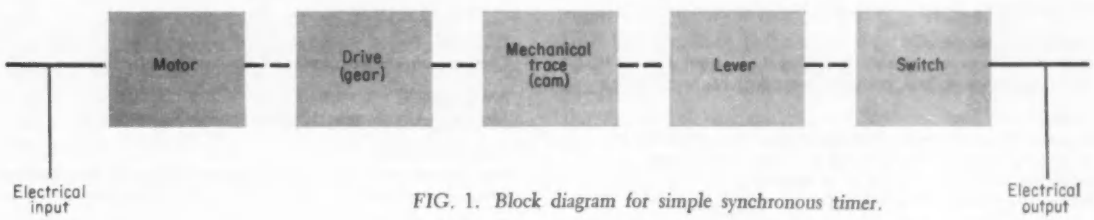

FIG. 1. Block diagram for simple synchronous timer.

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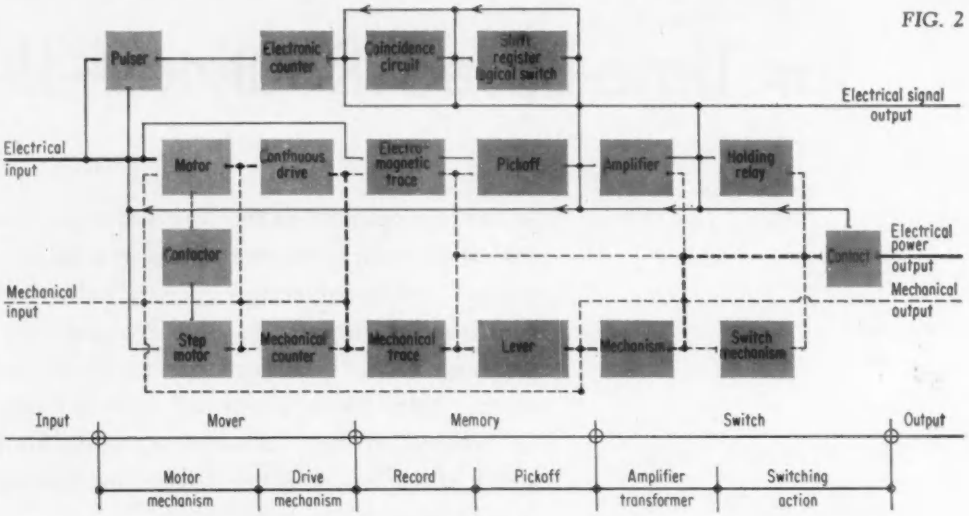
The first part of this article (CONTROL ENGINEERING, April 1958, page 92) told how the designer of time-based program controllers has at his disposal a vast array of components and techniques. While this is in many respects a good arrangement, it does burden the engineer with the responsibility of choosing the best combinations of hardware and method. Careful evaluation is called for. To aid in this evaluation, the concept of a "Total Block Diagram" has been evolved. It is intended as a universal criterion for pretesting controller designs in the light of the requirements of a particular application.

This design tool simply extends the idea that program controllers can be symbolized by block diagrams such as those widely used in many control fields. The block diagram for a simple synchronous timer, for example, is shown in Figure 1. Here, as usual, solid lines mean electrical connections; dotted lines represent mechanical linkages (shafts, levers, etc.). Now, if block diagrams were drawn for every conceivable program controller, a number of diagrams would be found to be identical except for the words written in the blocks. It is thus possible to reduce the number of different block diagrams by standardizing terms; that is, by using a single phrase to describe as many differently named, but functionally equivalent, elements as possible. For instance, components such as cams, grooved cylinders, notched discs, and punched tapes, may all be described as "mechanical traces".

The end-products of such standardization of ter-

Use this diagram to evaluate designs

FIG. 2



WHAT THE BLOCKS MEAN

ELECTRICAL INPUT
Alternating or direct current; also radiation energy

MECHANICAL INPUT
Any mechanical movements, including those from devices that are responsive to flow, pressure, temperature, and the like

PULSER
A device that produces electrical pulses from alternating or direct current; may be in the form of an electronic circuit or an electromechanical component such as a vibrator or motor-driven contactor

ELECTRONIC COUNTER
A nonmechanical counter with electrical output operating in decimal, binary, or other numbering system

COINCIDENCE CIRCUIT
A circuit or component that provides a signal or allows a signal to pass when an input quantity is identical with a reference quantity

SHIFT REGISTER
A device that transforms a sequence of signals (time distribution) into a parallel binary number (space distribution) or vice versa

LOGICAL SWITCH
An arrangement, such as a diode matrix, capable of directing a signal to one of several outputs

MOTOR
Any electrical or mechanical driving mechanism, not necessarily rotational; for example, an electric motor, a mechanical clockwork, or a solenoid

CONTINUOUS DRIVE
Any mechanism that changes a continuous mechanical input to a continuous mechanical output of another form; e.g., rotation to translation, or flow to rotation

ELECTROMAGNETIC TRACE
The form of the information recorded on media, such as magnetic tape and photographic film, that are designed to be read electrically

PICKOFF
Converts an electromagnetic trace into an electrical signal

AMPLIFIER
May also include a rectifier or nonholding relays

HOLDING RELAY
Any device with two stable states; examples are latching relays, magnetic cores and electronic flip-flops

CONTACTOR
Provides electrical pulses from a mechanical input (the necessary electrical power input is assumed)

STEP MOTOR
Produces mechanical motion in steps upon an electrical or mechanical input signal

MECHANICAL TRACE
The form of the information recorded on components such as cams, grooved cylinders, notched discs, punched cards, and drums carrying shaped conducting material

LEVER
Any device that reads a mechanical trace and makes information available in the form of mechanical movement

MECHANISM
Amplifies the lever movements and renders them into a more usable form

CONTACTS
The electrical contacts that are actuated either by the relay armature or by the switch mechanism

ELECTRICAL SIGNAL OUTPUT
Low-power electrical output; energy that provides intelligence

ELECTRICAL POWER OUTPUT
Electrical output above signal power level; energy that produces the desired action

minology are a much-reduced number of really different block diagrams, perhaps 20 or 30. And all of these diagrams can be fused into a comprehensive block diagram that pictures all possible controllers. This total block diagram is shown in Figure 2 and the standardized block titles are explained in the accompanying table.

The total block diagram is read by following any one path from left to right. Two things must be noted, however: no two horizontal lines can be used simultaneously (in parallel), as would be possible with an ordinary block diagram, and, where arrows so indicate, the line must be traced from right to left. Vertically, the diagram is divided into the three basic categories of mover, memory, and switch; and these categories are further subdivided as indicated. The placement of a box in any of these categories and subcategories is determined by its function; it does not matter whether the components designated by a box are by nature mechanical, electrical, or something else.

The block diagram describes a typical program controller as follows: an electric "motor" through a "continuous drive" (e.g., a gear, as opposed to a multispeed counter) moves a "mechanical trace" (e.g., a cam). The information represented by the cam is picked up by the "lever", which in turn actuates a "mechanism" that is mechanically connected to "electrical contacts", so that the final output is electrical. This path, indicated by the heavy lines in Figure 2, actually represents a rather simple timer. More complex controllers may consist of several channels, each including a trace, lever, switch, etc. But even such multiple instruments are adequately symbolized by the block diagram.

A number of boxes in the diagram represent design elements that are useful for special requirements. One such requirement is for the occurrence of a certain event after a precise long period of time. If this task is to be accomplished by a cam, it may be advisable to drive the cam by means of a step motor that is operated intermittently by electrical pulses. This arrangement is sufficiently common to warrant a "step motor" box in the diagram. The operating pulses are furnished by a motor-driven contactor. Change gears make it possible to adjust the speed of the contactor to suit various lengths of routines. A mechanical counter may be used instead of the step motor for intermittent movement of the mechanical trace.

The functional equivalence of electromagnetic and mechanical traces makes it convenient to locate one type above the other on the block diagram in Figure 2. The designer who is using magnetic tape also has a choice of drives: continuous motor, step motor, or mechanical counter. The electrical input needed for the magnetic recorder is shown as coming directly from the common electrical input because in this diagram the electrical input is always understood to be the required form.

Functional equivalence is also true of the pickoff (the magnetic head of the magnetic-tape reader) and the levers used for sensing the position of mechanical traces. Even the electronic amplifier, which is used to step up the low-level signal from the pickoff, has a mechanical counterpart in the form of systems made up of levers and linkages. The function of a holding relay is easily duplicated by an arrangement of levers or other mechanical elements.

The diagram has a special track for electronic digital programmers, reached either by tracing up after "pickoff" and then back, or by following to the right after "electronic counter". The first path includes a tape with a magnetic trace. The signals are fed through the pickoff to a diode shift register that contains a logical switch for selectively energizing output relays in a number of control channels. The second path covers digital programmers that do not require tape. In such units, an electronic counter or digital clock operating from a "pulser" (i.e., a source of ac voltage) provides pulses in time sequence. The pattern of these pulses at some predetermined time will agree with the settings of a "coincidence circuit"; when coincidence occurs, the pulse is directed by a logical switch to one of a number of output relays.

By using the backward-leading lines, the designer can "stretch" the total block diagram to accommodate the most flexible program controller. The procedure begins with the outline of a simple unit and adds the auxiliary features as required. For example, in the controller represented by the heavy lines in Figure 2, a motor drives a cam through gearing and the resulting movement is picked up by levers that actuate a contact. This simple design can be made more elaborate by using one of the arrowed right-to-left lines. Perhaps the designer wants to start an auxiliary timer. Then he would use either the electrical signal provided by the final switch (going back to the solid line), or some mechanical means (returning along a dotted line).

In the latter case, it is necessary to branch off after the "lever" box, and then move from right to left below the lower row of boxes before returning to the box labeled "motor." Here a new start, to encompass an additional program controller of any type, may be made. This might be a magnetic tape whose trace is picked off by magnetic heads, then amplified, rectified, and fed to relays. In such a case, the total programmer would be described as follows: an electric motor through suitable reduction gearing slowly rotates a shaft that carries several cams. The amplitude of the cams is picked off by mechanisms that actuate a corresponding number of contacts. Upon closure of any one contact, another electric motor is started to drive a tape mechanism. The tape signal, which will be assumed to be analog, is amplified and rectified, and used to initiate some action. Although only hypothetical, this arrangement could be useful if a rather

intricate signal pattern were required during or after a long period of time.

Because program controllers such as the one just described double back through the block diagram, they pass a memory box twice. The first memory (here a cam) is usually the "event" memory, which defines the time when something is to happen. The second memory (here a magnetic tape) controls the duration and repetition of the signal, thus determining what will occur. This second (tape) memory might provide several channels (amplifiers, rectifiers, relays, etc.) to control different functions after the initial starting signal has been produced by the event programmer.

Use of block diagram

Because it includes a variety of hardware and a wide choice of interconnections, the total block diagram obviously covers a large number of designs for program controllers. It is therefore well-suited as a tool for classifying and clarifying the working principles of programmers: it allows the designer to check on new or allegedly new proposals, and to put various schemes in a logical order. Also, by emphasizing the functional similarity of certain mechanical and electrical components, the diagram can suggest equivalent components that may be more suitable for a particular purpose.

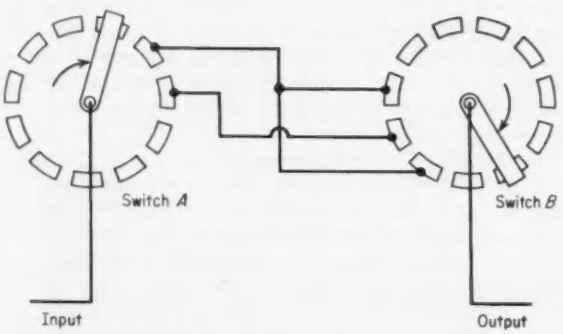


FIG. 3. Coincidence circuit comprising two rotary switches in series.

An example will clarify this: assume that 20 signals are to be produced at 20 different times within a 5-min span and that each signal must be transmitted with an accuracy of plus or minus 0.1 sec from the selected moment. The first suggestion, namely an ordinary cam controller driven by a motor through a continuous gear drive, is rejected because it is not accurate enough and is not easily adjustable. The designer now refers to the diagram and finds the following possibilities:

1. A step motor driving the cams directly (by-passing the "mechanical counter" block). This arrangement provides good definition in time, but has some limitation in adaptability because no action can be initiated when the step motor is at rest.
2. A synchronous motor driving a mechanical counter equipped with notched wheels. At times predetermined by the counter numbers, levers fall into the notches to actuate switches or contacts. This is basically a good design, but for the sake of this example assume that the plan is not workable, possibly because it is too difficult to provide for the easy adjustability of the set times or because an environment with severe vibration is present. The diagram then suggests a third design approach.
3. An electronic counter with an electronic coincidence circuit and 20 holding relays. This will result in a versatile, small, light, and reliable programmer which satisfies this example problem. However, it is probably expensive for most industrial uses.

Imagination is sometimes required to translate the titles and explanations of the table into applicable hardware design. For instance, a controller may include a rotary switch with many contacts, only a few of which are connected to controlled elements such as relays or secondary programmers. The contact array of such a switch can be considered a mechanical trace, for according to the table, a mechanical trace is implied by the words "shaped conducting material". In tracing this rotary switch controller on the diagram the designer would go from the "mechanical trace" block directly to "contact".

In another case, it may not be immediately apparent why the box "coincidence circuit" is in the same vertical bracket with (i.e., functionally related to) the "mechanical trace" block. But a little thought reveals the possibility of connecting two switches in series so as to provide electrical contact only when both are in a corresponding position. Such a combination of switches, Figure 3, provides a pulse at three different times. Since switch *A* rotates slowly and switch *B* fast, the *B* wiper will pass over the wired contacts several times before output action occurs.

The point is that it is possible to arrive at an optimum controller regardless of whether the design is mechanical, electrical, optical or something else. Each design must be carefully and completely drafted, criticized, redesigned, developed, tested, and evaluated before a final selection is made. It should not be decided, before very carefully trying to develop each basic idea to the utmost, that "cams are no good here," or that "two rotary switches in series are not reliable," or that they "do not provide enough flexibility". Some approaches that seem impractical at first may be perfected by miniaturization, by further development of the idea of multiple arrangements, by unearthing kinetic equivalents (reversing the role of moving and static parts), or by using novel materials. The best programmer for an application will often depend more on careful development than on choice of a basic scheme.

Dynamic Representation of Lossless Distributed Systems

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A distributed-parameter system is one in which variations in space occur simultaneously with transient variations. Whenever the variations with respect to space are as large as the variations with respect to time, that is, whenever the physical length approaches the characteristic wave length, a lumped-parameter approximation of the dynamics is inaccurate, and partial differential equations must be used. From the partial differential equations for a hydraulic line this data file developes a simple way to represent transient behavior with time-delay operations.

Figure 1 shows the representation arranged for study by an analog or digital computer. It fits shafts, rods, cables, hydraulic conduits, and electrical transmission lines in which losses are small. The table (next page) lists the appropriate expressions for them. The representation does not fit shock tubes and very small pneumatic tubes, in which the energy dissipated per unit length is a significant fraction of the stored energy. When, as in these cases, energy dissipation cannot be neglected, the lossless representation will describe the wavelike action of the system and dissipative elements lumped at either end of the block diagram will describe the frictional effects[1].

The behavior of a frictionless and uniform hydraulic transmission line illustrates the analytical development. The same development, with the variables and coefficients listed in the table, applies to other transmission elements.

Starting with the fluid element shown in Figure 2, compressibility and Newton's Second Law lead to the following pair of equations.

$$\frac{\partial P}{\partial t} = -\beta \frac{\partial V}{\partial x} = -C^2 \rho \frac{\partial V}{\partial x} \qquad (1)$$

$$\frac{\partial P}{\partial x} = -\rho \frac{\partial V}{\partial t} = -\frac{\beta}{C^2} \frac{\partial V}{\partial t} \qquad (2)$$

where

P = fluid pressure, psi
V = fluid velocity, in/sec
β = fluid bulk modulus, psi
ρ = fluid density, lb-sec^2/in.^{4}
C = $(\beta/\rho)^{1/2}$, the propagation velocity

The general form of the solution that satisfies either of Equations 1 and 2 is

$$P = F_1 (t + x/C) + F_2 (t - x/C) \qquad (3)$$

where F_1 and F_2 are arbitrary functions.

Differentiating P partially with respect to x and t separately and substituting the results in Equations 1 and 2 gives

$$\frac{\partial V}{\partial x} = -\frac{1}{\beta} \frac{\partial P}{\partial t} = -\frac{1}{\beta} [F_1' (t + x/C) + F_2' (t - x/C)] \qquad (4)$$

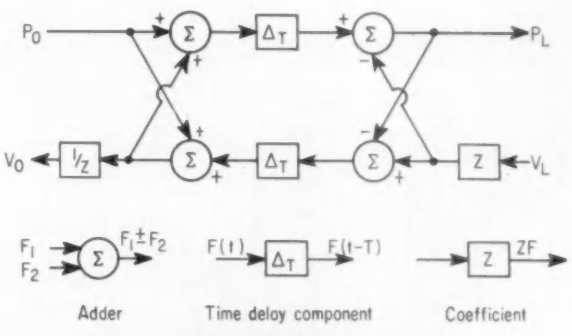

FIG. 1. Block diagram representation of lossless distributed system.

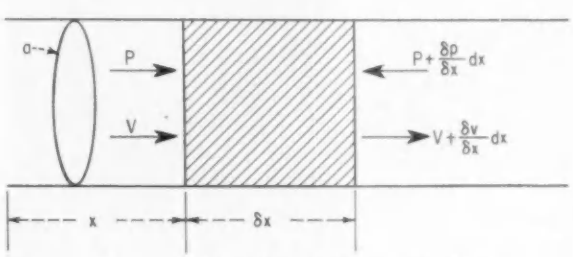

FIG. 2. Differential pressures developed across the incremental length of a fluid element.

RELATED VARIABLES AND COEFFICIENTS OF DISTRIBUTED SYSTEMS

	Generalized Effort	Generalized Flow	Z, Impedance	C, Propagation Velocity
Fluid Conduits	P, lb/in.^{2}	V, in./sec	$\sqrt{\rho\,\beta}$, $\frac{\text{lb-sec}}{\text{in.}^3}$	$\sqrt{\frac{\beta}{\rho}}$, in./sec
	P, lb/in.^{2}	Q, in.^{3}/sec	$\frac{\sqrt{\rho\,\beta}}{a}$, $\frac{\text{lb-sec}}{\text{in.}^5}$	$\sqrt{\frac{\beta}{\rho}}$, in./sec
	P, lb/in.^{2}	W, lb/sec	$\frac{1}{ga}\sqrt{\frac{\beta}{\rho}}$, $\frac{\text{sec}}{\text{in.}^2}$	$\sqrt{\frac{\beta}{\rho}}$, in./sec
	H, in.	Q, in.^{3}/sec	$\frac{1}{ga}\sqrt{\frac{\beta}{\rho}}$, $\frac{\text{sec}}{\text{in.}^2}$	$\sqrt{\frac{\beta}{\rho}}$, in./sec
Rods (longitudinal stress waves)	σ, lb/ in.^{2}	V, in./sec	$\sqrt{\rho\,E}$, $\frac{\text{lb-sec}}{\text{in.}^3}$	$\sqrt{\frac{E}{\rho}}$, in./sec
	F, lbs	V, in./sec	$a\sqrt{\rho\,\beta}$, lb-sec/in.	$\sqrt{\frac{E}{\rho}}$, in./sec
Shafts (torsional waves)	M, in.-lb	ω_1, rad/sec	$I_P\sqrt{G\,\rho}$, in./lb-sec	$\sqrt{\frac{G}{\rho}}$, in./sec
Electrical (transmission lines)	E, volts	I, amps	$\sqrt{\frac{l'}{c'}}$, $\frac{\text{volt}}{\text{amp}}$	$\frac{1}{\sqrt{l'\,c'}}$, in./sec

a = cross-sectional area of fluid signal transmission conduit, in.^{2}
g = acceleration of gravity, in./sec^2
E = modulus of elasticity, lb/in.^{2}
I_P = polar moment of inertia, in.^{4}
G = modulus of rigidity, lb/in.^{2}
l' = inductance per unit length, henries/in.
c' = capacitance per unit length, farads/in.

$$\frac{\partial V}{\partial t} = -\frac{1}{\rho}\frac{\partial P}{\partial x}$$

$$= -\frac{1}{\rho C}\left[F_1'(t + x/C) - F_2'(t - x/C)\right] \quad (5)$$

where $F'(\xi) = \partial F(\xi)/\partial\xi$

The expression for V is deduced from Equations 4 and 5

$$V = (1/\rho\,\beta)^{1/2}\left[-F_1(t + x/C) + F_2(t - x/C)\right] \quad (6)$$

By defining $Z = (\rho\beta)^{1/2}$ as the frictionless characteristic impedance, Equation 6 can be rewritten as:

$$ZV = -F_1(t + x/C) + F_2(t - x/C) \quad (7)$$

Letting the subscript o denote $x = 0$, the upstream position, and the subscript L denote $x = L$, the downstream position, and defining $T = L/C$ as the signal propagation time between the two positions, Equations 3 and 7 become

$$P_o = F_1(t) + F_2(t) \quad (8)$$
$$P_L = F_1(t + T) + F_2(t - T) \quad (9)$$
$$ZV_o = -F_1(t) + F_2(t) \quad (10)$$
$$ZV_L = -F_1(t + T) + F_2(t - T) \quad (11)$$

By adding Equations 8 and 10 and Equations 9 and 11 separately, four other relations result:

$$P_o + ZV_o = 2F_2(t) \quad (12)$$
$$P_o - ZV_o = 2F_1(t) \quad (13)$$
$$P_L + ZV_L = 2F_2(t - T) \quad (14)$$
$$P_L - ZV_L = 2F_1(t + T) \quad (15)$$

Eliminating the functions F_1 and F_2 and rewriting Equations 12 and 15 in a slightly different form:

$$[P_o + ZV_o](t - T) = 2F_2(t - T) \quad (12)$$
$$[P_L - ZV_L](t - T) = 2F_1(t) \quad (15)$$

the desired final equations are obtained:

$$[P_o + ZV_o](t - T) = P_L + ZV_L \quad (16)$$
$$[P_L - ZV_L](t - T) = P_o - ZV_o \quad (17)$$

The block diagram shown in Figure 1 simulates, with time-delay components, these two equations, generally known as the characteristic equations. The upper signal flow path in the figure represents waves traveling downstream and the lower one represents waves traveling upstream. When the downstream travel time is not identical with the upstream travel time, due to a mean flow, the delay times in the block diagram can be modified accordingly. Because the block diagram for a distributed parameter element is in terms of a four-terminal network, it may now be readily incorporated with representations of other system elements, distributed or not.

REFERENCE:

1. COMPUTER REPRESENTATION OF ENGINEERING SYSTEMS INVOLVING FLUID TRANSIENTS, F. D. Ezekiel and H. M. Paynter, "ASME Trans," Vol. 79, No. 8, '57, pp. 1,840-1,850.

Process Analysis Plus Analog Simulation Yields Better Mill Controls

THE GIST: Using noncontacting thickness gages it is possible to design rolling mill controls that regulate thickness itself. The first step in designing such controls is to analyze the rolling process. This study starts with a new look at the characteristics of the single-stand mill, which in turn provides the background for an examination of the tandem mill, commonly used in U. S. production. Equations describing steady state performance can be developed for both a single stand mill and a tandem mill, but the dynamic analysis of the latter introduces a degree of complexity that suggests the use of an analog computer for their solution. What is done for manual control of rolling mills supplies the clues for development of automatic systems.

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The noncontacting radiation gage for thickness measurement provides control engineers with a tool to design rolling mill controls that regulate thickness itself. Since the rolling process then becomes a part of the regulating loop, it has to be understood before the control system can be designed. Analysis shows that the frequently-used tandem mill has a very complicated transfer function; therefore, analog simulation is a useful way to solve the derived equations.

Previously the rolling process was not controlled directly; it was sufficient then to analyze only the regulating system. If a voltage regulator was used, for example, the study included the reference and feedback circuit, motor field exciter, generator, motor, IR drop compensation circuit, and the stabilizing circuits. To explain the new approach, it is first necessary to take a new look at the physical characteristics of the mill. Although both nonferrous and ferrous metals are reduced in rolling mills, only steel sheet-rolling will be covered here.

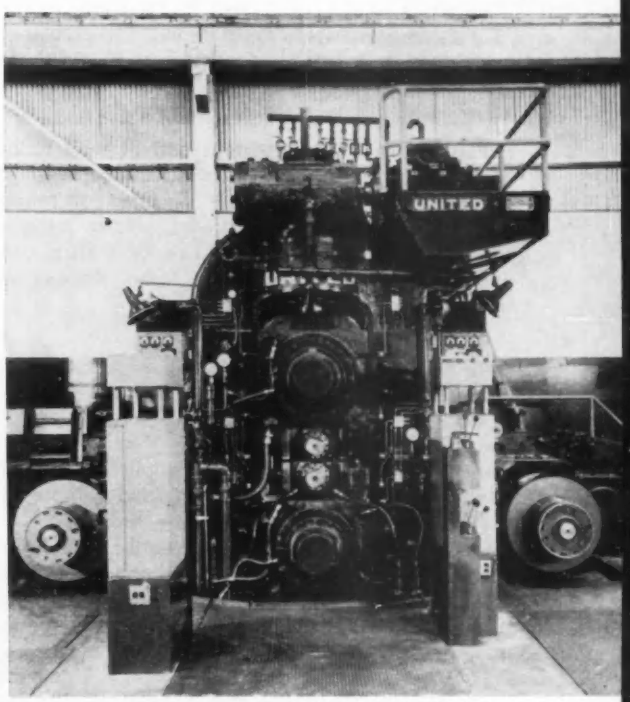

FIG. 1. Single stand mill reduces thickness of strip in several passes. Thickness is controlled by changing entry or exit tension or moving screw in the mill housing to apply force to the backup rolls.

ROLLING MILL CHARACTERISTICS

What happens in a single stand mill provides the background for understanding the more complex tandem mill. A typical mill (Figure 1) in several passes reduces 44-in.-wide strip from 100 mils to less than 10 mils at delivery speeds up to 3,000 fpm. The pressures required develop screwdown forces of several millions of pounds. This force, applied to the backup rolls through screws in the mill housing, makes the metal flow plastically. In addition, tension may be applied to the strip on both the entry and exit side of the mill.

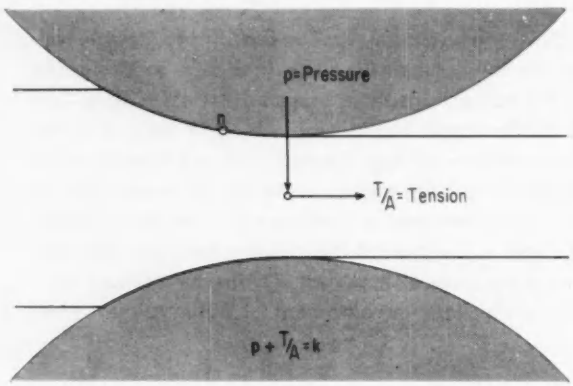

FIG. 2. Schematic of roll bites. According to plastic flow theory, at any point in the roll bite the sum of the vertical compressive stress and the horizontal tensile equals the yield stress. Point n is the intersection of neutral plane with roll arc of contact.

Plastic flow is an important part of steel rolling analysis. Since the strip is wide compared to its thickness, the flow is in the direction of rolling. According to plastic flow theory, at any point in the roll bite (Figure 2) the sum of the vertical compressive stress and the horizontal tensile stress equals the yield stress. Or,*

$$p + \frac{T}{A} = K$$

where p = pressure, lb per sq in.
T/A = tension, lb per sq in.
K = yield stress, lb per sq in.

This equation suggests that the application of tension to the strip reduces the required compressive stress supplied by the work rolls.

One other characteristic of the mill is significant. The mill housing, screws, backup rolls, and work rolls behave in combination like a huge spring. For the forces encountered in the working range of the mill, there is a linear relationship between change in workroll force and change in workroll opening. Applying tension to the strip lessens the required roll pressure. The spring-like action of the rolls causes them to move together until a new point of equilibrium is reached.

This indicates two ways to control exit thickness: increasing (or decreasing) entry or exit tension, and lowering (or raising) the screws.

As the material in the roll bite is reduced, each successive cross section moves at a higher speed than the previous one. There is a neutral plane on the roll arc of contact where the roll peripheral velocity equals the strip velocity. If the rolls are to grip the strip, the neutral plane velocity must be greater than the entry velocity and less than the exit velocity. On the entry side of this plane, the rolls move faster than the strip; on the delivery side, the strip moves faster than the rolls. An increase of incoming tension causes the neutral plane to move toward the exit; an increase of outgoing tension causes the neutral plane to move toward the entry. The limiting case: when the work rolls begin to slip. If the incoming tension is increased gradually, the work rolls will find it increasingly difficult to pull the strip through. Eventually the rolls will be moving faster than the strip throughout the entire roll gap—so the work rolls slip.

Steady-state equations

Changes in tensions, screw position, and entry thickness will produce changes not only in exit thickness, but also in the screwdown force required and the torque from the motor driving the work rolls. Introducing the concept of constant mass flow in the roll arc of contact and linear spring in the mill permits the derivation of linear equations over the range of expected variations. These predict exit thickness, tension, and screw position.

$$\frac{\Delta h_o}{h_o} = C_1 \frac{\Delta h_i}{h_i} + C_2 \frac{\Delta T_i}{A_i} + C_3 \frac{\Delta T_o}{A_o} + C_4 \Delta S \qquad (1)$$

$$\frac{\Delta v_i}{v_i} = C_5 \frac{\Delta h_i}{h_i} + C_6 \frac{\Delta T_i}{A_i} + C_7 \frac{\Delta T_o}{A_o} + C_8 \Delta S + \frac{\Delta v_n}{v_n} \qquad (2)$$

$$\frac{\Delta v_o}{v_o} = C_9 \frac{\Delta h_i}{h_i} + C_{10} \frac{\Delta T_i}{A_i} + C_{11} \frac{\Delta T_o}{A_o} + C_{12} \Delta S + \frac{\Delta v_n}{v_n} \qquad (3)$$

$$\frac{\Delta \tau_m}{\tau_m} = C_{13} \frac{\Delta h_i}{h_i} + C_{14} \frac{\Delta T_i}{A_i} + C_{15} \frac{\Delta T_o}{A_o} + C_{16} \Delta S \qquad (4)$$

where

$\frac{\Delta h_o}{h_o}$ = change in exit thickness from nominal per unit

$\frac{\Delta h_i}{h_i}$ = change in entry thickness from nominal per unit

$\frac{\Delta T_i}{A_i}$ = change in entry tension—millions of psi

$\frac{\Delta T_o}{A_o}$ = change in exit tension—millions of psi

ΔS = change in screw position (positive upward)—inches

$\frac{\Delta v_i}{v_i}$ = change in entry speed of strip from nominal per unit

*For theoretical justification, see reference 1.

$\frac{\Delta v_o}{v_o}$ = change in exit speed of strip from nominal per unit

$\frac{\Delta v_n}{v_n}$ = change in neutral plane speed from nominal per unit

$\frac{\Delta \tau_m}{\tau_m}$ = change in motor torque from nominal per unit

These equations are useful in steady-state considerations. The simplest rolling mill consists of one reduction stand, an unwind reel, and a wind reel. These reels apply tension to the strip; an armature current regulator on the reel motor acts to hold constant tension during steady-state operation. To study the mill transiently it is necessary to derive motor equations relating speed, motor load torque, and current. Derived for the elastic strip between reel and mill rolls, these equations calculate (1) entry tension from unwind reel velocity and entry speed to the roll bite, and (2) exit tension from exit speed of roll bite and wind reel velocity.

(One other factor is considered. In paper calendering machines and rotary printing presses, if an instantaneous change in speed is made on a winding reel, the tension between it and the previous stand will increase exponentially with a time constant equal to the transport time. In a reduction mill, however, an increase of speed of the winding reel will begin to increase the tension, but that increase will shift the neutral plane of the last reduction stand toward the entry. This, in turn, increases the exit speed with respect to the neutral plane (or mill motor) speed. And the mill motor speed is essentially constant.)

A change in the elongation Δe between the mill stand and the winding reel results from velocity difference between the strip leaving the stand and that entering the reel.

$$\Delta e = v_0 \int_o^t \left[\frac{\Delta v_R}{v_R} - \frac{\Delta v_o}{v_o} \right] dt \qquad (5)$$

For small elongations in an elastic material of length L, elongation is equal to the product of tension and length divided by the modulus of elasticity E.

$$\Delta e = \frac{L}{E} \frac{\Delta T}{A} \qquad (6)$$

Equations 5 and 6 may be equated, yielding

$$\frac{\Delta T}{A} = \frac{\Delta v_0 E}{L} \int_o^t \left[\frac{\Delta v_R}{v_R} - \frac{\Delta v_0}{v_0} \right] dt \qquad (7)$$

Ignoring changes in tension between the unwind reel and the mill stand helps to simplify these equations. Consider, first, that no reduction is being taken in the mill stand; then the velocity of the neutral plane is equal to the change in strain between the mill stand and the reel.

$$\frac{\Delta v_0}{v_0} = \frac{\Delta v_n}{v_n} + \frac{\Delta e}{L} = \frac{\Delta v_n}{v_n} + \frac{1}{E} \frac{\Delta T}{A} \qquad (8)$$

Substituting Equation 8 in Equation 7,

$$\frac{\Delta T}{A} = \frac{E}{1 + p \frac{L}{v_0}} \left[\frac{\Delta v_R}{v_R} - \frac{\Delta v_n}{v_n} \right] \qquad (9)$$

For this condition, the time constant of tension buildup is equal to the transport time between the mill stand and the winding reel.

If, in addition, reduction is taken in the mill stand, Equation 8 will have an additional term,

$$\frac{\Delta v_0}{v_0} = \frac{\Delta v_n}{v_n} + \frac{1}{E} \frac{\Delta T}{A} + \frac{1}{K} \frac{\Delta T}{A} \qquad (10)$$

where K can be considered to be the "modulus of plasticity". For a typical case this "modulus" would be 1.0 million psi. Substituting Equation 10 in Equation 7,

$$\frac{\Delta T_5}{A_5} = \frac{1 + \frac{E}{K}}{1 + p \frac{L}{v_O} \frac{1}{1 + \frac{E}{K}}} \left[\frac{\Delta v_R}{v_R} - \frac{\Delta v_n}{v_n} \right] \qquad (11)$$

Using values for E and K of 30 million psi and 1.0 million psi respectively,

$$\frac{\Delta T}{A} = \frac{0.032E}{1 + \text{p}0.032 \frac{L}{v_0}} \left[\frac{\Delta v_R}{v_R} - \frac{\Delta v_n}{v_n} \right] \qquad (12)$$

Equation 12 shows that the gain between a speed change and a tension change is reduced greatly when reduction is being taken in a stand. In addition, since L/v_o is in the order of 1 sec, the effective time constant for tension buildup is reduced to a negligible value.

Therefore, for a single-stand reducing mill the equations of rolling are linear and algebraic, with no time constants.

TANDEM MILL ANALYSIS

Not so simple is the analysis of rolling in a tandem mill (all the high production mills in the U.S. are tandem mills). A typical reduction schedule for such a mill (Figure 3): strip 30 in. wide enters the first stand at about 90 mils, is reduced in the successive stands to 63 mils, 39 mils, 23 mils, 14 mils, and is delivered at 8 mils. There is, of course, tension coupling between the stands, and the time constants associated with tension build-up are negligible.

However in the tandem mill the delivered thicknesses from each of the stands varies. These propagate to the next stand. As a result, in addition to the tension coupling which is essentially instantaneous, there is a coupling between stands through a transport delay. This complicates the mill transfer function, which as a result cannot be simplified mathematically by the algebraic manipulation used to handle systems consisting entirely of minimum phase transfer functions. Analog simulation is indi-

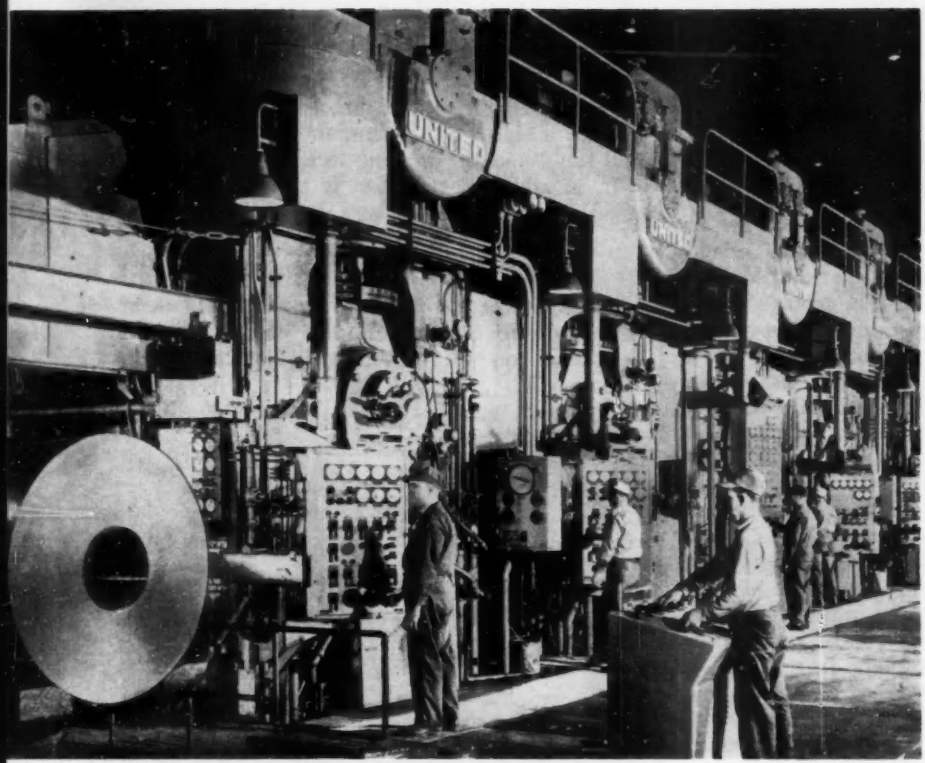

FIG. 3. Analysis of rolling in a tandem mill is completed by the interrelations of each stand—tension coupling between the stands.

cated, but because there is no commercially available transport delay simulator at present, even this must be approximate.

Before considering computer solution of the equations, manual thickness control of many five-stand tandem mills should be examined. The winding reel acts to hold the reeling tension constant. Therefore, if the speed of the stand-five motor is increased, the tension between the fourth and fifth stands increases. This will reduce the thickness of the strip delivered from the fifth stand. As a secondary effect, however, the increased tension between stands four and five will reduce the thickness delivered from stand four. After the propagation time has elapsed, the thinner strip will reach the fifth stand, the reduction required in the fifth stand will be less, and the rolls will move together an additional amount, producing an even thinner strip.

Manual control

The operator can compensate for measured thickness deviations by manually controlling drive-motor speed. The limitations: time constants in the motor-control circuit and the propagation time. And unless the winding reel control can "stay with" the stand-five speed changes, it, too, can be an important factor in limiting performance. When the measured tension between the fourth and fifth stands gets above the value which is considered good practice, an operator lowers the stand one screwdown so that a greater reduction is taken in the first stand. After several seconds have passed, the strip rolled under these conditions will reach the fifth stand. Here less reduction is required, and less tension needed to produce material of the desired thickness. The addition of a thickness measuring device between the first and second stands permits an operator to reposition the screwdown of the first stand to hold thickness delivered nearly constant. It has the effect of keeping the tension between stands four and five at a safe value and avoids "after the fact" type of operation described above.

Automatic control

A relatively simple system of automatic control is suggested by experience with manual control. At the first stand the thickness deviation signal from a noncontacting radiation gage located between the first and second stands is amplified and used to control the screwdowns of the first stand. On most tandem mills the screwdowns are operated from dc motors with fixed fields. Armature voltage is applied from a constant potential bus by magnetic control operating contactors. Since, upon initiating a correction, time must elapse before the screwdown motors start to move and the altered thickness reaches the thickness gage, a sampling-type control is the most generally applicable.

A tandem cold mill is threaded at low speed and quickly accelerated to a much higher running speed. Magnetic control circuitry can provide "off-time", which is inversely proportional to mill speed. With a constant potential source of armature voltage the amount of screwdown movement, and therefore the

amount of thickness error correction, is proportional to the time the voltage is applied. The "on-time" is made proportional to thickness deviation. The net result is a sampling-type control that is proportional in nature. This is the "coarse" control.

Since the material must pass through four more reducing stands, an additional point of correction is necessary. This point is best located at the delivery stand. Again experience with manual control suggests a promising solution. A noncontacting gage is placed between the last reducing stand and the winding reel. When there is a deviation in strip thickness from the reference value set into the gage, a synchro in the gage develops an ac signal, the amplitude of which is proportional to deviation. A discriminator circuit produces a dc signal proportional to deviation. This signal is then amplified and fed into the stand-five drive motor circuits to produce speed changes which will act to restore thickness to the desired value. This portion of the system is called the vernier control. It is similar functionally to what an operator accomplishes manually.

To design the control for good transient performance it is necessary to study analytically the interactions of the stand-five motor control and the winding reel control, and to make modifications in their circuits to minimize the adverse effects. A secondary thickness change, created in the fourth stand (which propagates to the fifth), must be considered.

USING THE ANALOG COMPUTER

It is necessary then to represent on an electronic analog computer the rather complex system of mechanical interactions in the mill, electrical system constants, and the transport delays between stands four and five, and stand five and the radiation-type gage. A preliminary analysis is performed to investigate steady-state behavior of the complete mill, something which requires solution of several simultaneous equations with many inputs. A digital computer and matrix inversion techniques are used to solve these equations. As a result of the preliminary study it was found that it is necessary to represent only the fourth stand, fifth stand, and the winding reel on the analog computer to study the transient performance of the vernier gage control. Figure 4 shows the block diagram of the mill equations in detail and the control and drive motors symboli-

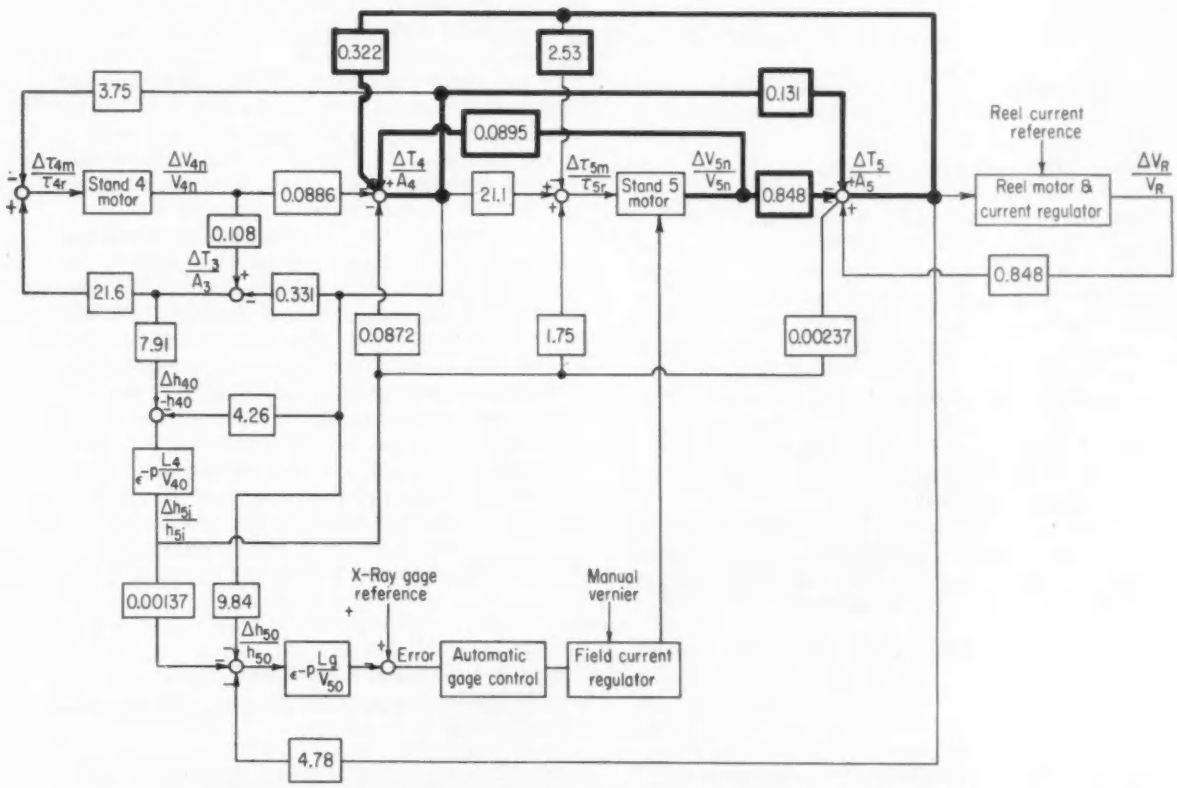

FIG. 4. Block diagram of the mill equations (in detail) and the control and motors (symbolically). Resultant changes in the tensions may be calculated by taking numerical values for the several paths (in bold lines).

cally. The many interactions in the process itself are apparent from this diagram.

The variables shown in the diagram are:

$\frac{\Delta h_{40}}{h_{40}}$ = change from nominal of stand-four exit thickness

$\frac{\Delta h_{50}}{h_{50}}$ = change from nominal of stand-five exit thickness

$\frac{\Delta h_{5i}}{h_{5i}}$ = change from nominal of stand-five entrance thickness $\Delta h_{40}/h_{40}$ delayed by the transport time from stand four to stand five)

$\frac{\Delta T_3}{A_3}$ = change in tension between stands three and four

$\frac{\Delta T_4}{A_4}$ = change in tension between stands four and five

$\frac{\Delta T_5}{A_5}$ = change in tension between stand five and winding reel

$\frac{\Delta v_{4n}}{v_{4n}}$ = change from nominal of stand four neutral plane = speed

$\frac{\Delta v_{5n}}{v_{5n}}$ = change from nominal of stand five neutral plane = speed

$\frac{\Delta v_R}{v_R}$ = change from nominal of winding reel speed

$\frac{\Delta \tau_{4m}}{\tau_{4r}}$ = change from nominal of stand four motor load torque

$\frac{\Delta \tau_{5m}}{\tau_{5r}}$ = change from nominal of stand five motor load torque

To understand the meaning of the block diagram and the many interactions of the process shown by it, consider that the speed of stand five is instantaneously increased 1 percent ($\Delta v_{5n}/v_{5n} = 0.01$). At the first instant the reel current regulator will not have had time to move, so reel speed $\Delta v_R/v_R$ will not have changed. Although the torque on the stand-four motor will increase instantaneously, the speed cannot. And although the thickness delivered from stand four, $\Delta h_{40}/h_{40}$, will increase instantaneously it will not arrive at stand five until the transport time has elapsed. Thus, the only paths open to the speed change in affecting the thickness of strip delivered from the mill, $\Delta h_{50}/h_{50}$, are through tension changes $\Delta T_4/A_4$ and $\Delta T_5/A_5$. However, there are a number of paths the speed change can take to affect the tensions themselves.

Under these conditions the resultant change in the tensions may be calculated by taking numerical values for the several paths from the block diagram. These paths are shown in heavy lines.

$$\frac{\Delta T_4}{A_4} = [+0.0895 - 0.848(-0.322)]\frac{\Delta v_{5n}}{v_{5n}} - 0.322(0.131)\frac{\Delta T_4}{A_4}$$

$$\frac{\Delta T_5}{A_5} = [-0.848 + 0.0895(0.131)]\frac{\Delta v_{5n}}{v_{5n}} - 0.322(0.131)\frac{\Delta T_5}{A_5}$$

Carrying out the indicated operation:

$$\frac{\Delta T_4}{A_4} = 0.348\frac{\Delta v_{5n}}{v_{5n}} = 0.348(0.01) = 0.00348 \times 10^6 \text{ psi}$$

$$\frac{\Delta T_5}{A_5} = -0.802\frac{\Delta v_{5n}}{v_{5n}} = -0.802(0.01) = -0.00802 \times 10^6 \text{ psi}$$

Therefore the change in delivered thickness at the first instant will be:

$$\frac{\Delta h_{50}}{h_{50}} = -9.84\frac{\Delta T_4}{A_4} - 4.78\frac{\Delta T_5}{A_5}$$
$$= -9.84(0.00348) - 4.78(-0.00802)$$
$$= 0.0041 \text{ or } 0.41 \text{ percent}$$

The result shows that if the speed of stand five is increased 1 percent instantaneously, the delivered thickness will increase 0.41 percent, since the tension between the fifth stand and the winding reel decreases much more than tension between the fourth and fifth stand increases.

If the reel regulating system could respond instantaneously there would be no change in tension $\Delta T_5/A_5$ and the delivered thickness change at the first instant would be

$$\frac{\Delta h_{50}}{h_{50}} = 0.0895(-9.84)\frac{\Delta v_{5n}}{v_{5n}} = 0.0895(-9.84)(0.01)$$
$$= -0.00881 \text{ or } -0.81 \text{ percent}$$

Under these conditions the speed increase produces a thickness decrease. The transient performance of the winding-reel control is thus shown to have a very significant effect on the success of a system which controls the speed of stand five to regulate delivered thickness.

In the steady state there will be a change in the thickness of material entering stand five and there may be some change in the speed of stand four due to the change in load torque. These effects will result in a further small change in delivered thickness.

The analog computer study shows the functional requirements of the gage control loop; that is, the total amplification, the maximum allowable time constants of the amplifiers, and the series stabilization. Since the transient characteristics of the winding-reel control are so important to the gage-control performance, the optimum adjustment of the reel control is also determined. This entire activity is coordinated with the control system design both in the design stage and during the first field tests. The analytical study in the preliminary design stage provides an understanding of the process and its control, which results in a better system and in reduced field engineering time.

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Dual-Mode Servo Compensation

THE GIST: A form of nonlinear compensation, the "dual-mode" technique provides continuous proportional control with small error and error rate signals, and rapid switching to full saturating torque whenever the error or the error rate of change becomes significant. The compensation unit consists of a computer coupled to a fast spdt switching relay. In operation, the computer takes the first derivitive of the error signal, multiplies it by a variable gain factor, and feeds the result, along with the original error signal, into an adder. The sum of these voltages is applied to the coil of the switching relay, and when high enough will operate the contacts.

Relatively inexpensive, the computer-relay combination may improve response by as much as 400 percent in systems involving high or rapidly changing inputs. On the negative side, it offers little improvement in the operation of small ac instrument servos.

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A logical outgrowth of earlier efforts to provide nonlinear compensation for a servo system, the dual-mode technique described here offers (1) continuous control for small errors and error rates, and (2) full saturating torque for large values of these same variables.

The heart of dual-mode operation is a computer which switches the system from one operating mode to the other. Actually the computer performs several functions. It senses magnitude, polarity, and time rate of change of the error signal and, using these facts, calculates the proper time to switch the system from one mode to another. Servo parameters are fed into the calculator to provide more information about correct switching time.

For large errors, the system acts somewhat like a relay servo, the difference being that saturation torque is applied to the driving motor only until the error has reached about half the original value (for a second order system with no damping). Then reverse saturation torque decelerates the output uniformly to bring the error close to zero without any tendency to overshoot. At very small errors, the system is switched over to proportional or continuous control. Thus dual-mode operation provides the stability and accuracy of proportional control at small error signals and the advantages of relay control for large error signals.

Dual-mode operation has been shown to have definite advantages over the conventional servomechanism. However, in many cases, the expense and complexity of the computer may overshadow the advantages it offers. This paper describes a small, practical computer for simplified dual-mode operation.

Switching

The actual switching operations of the computer must be very fast compared to the time lags in the servo system itself. Vacuum-tube switching circuits, generally used for this purpose, become somewhat complicated and expensive. With fast enough response, a single spdt relay will accomplish the work of several tubes and their associated circuits. The relay actually used in the computer described here is a very small, lightweight, commercially available (Barber-Colman AYLZ 2203) unit with spdt contacts rated at 28 volts, 0.5 amp. Coil voltage is 24 volts with 30-ma maximum current. The unit has two coils with 940 ohms dc resistance in each. A current difference of 1 ma between the two coils will operate the relay. A series of response time

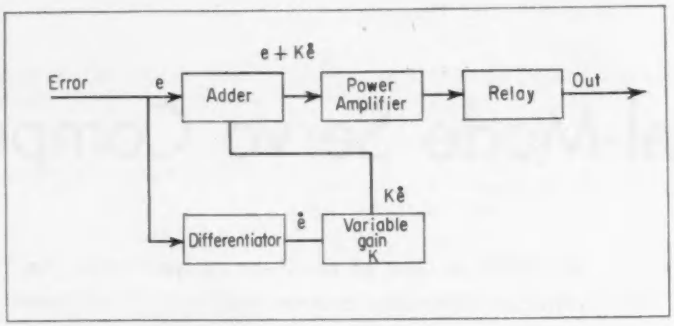


FIG. 1. Block diagram of computer and relay compensation unit.

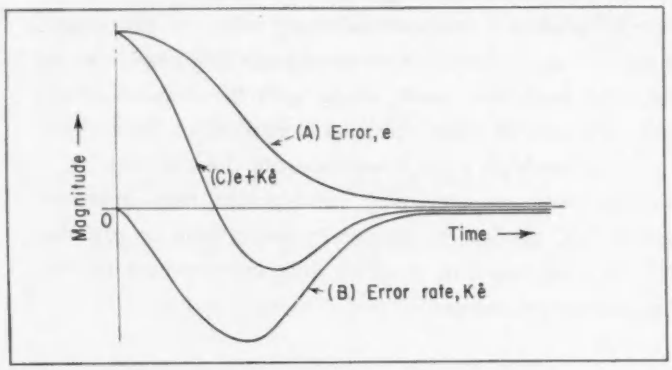


FIG. 2. Typical error, error rate, and e + Kė curves for a compensated system.

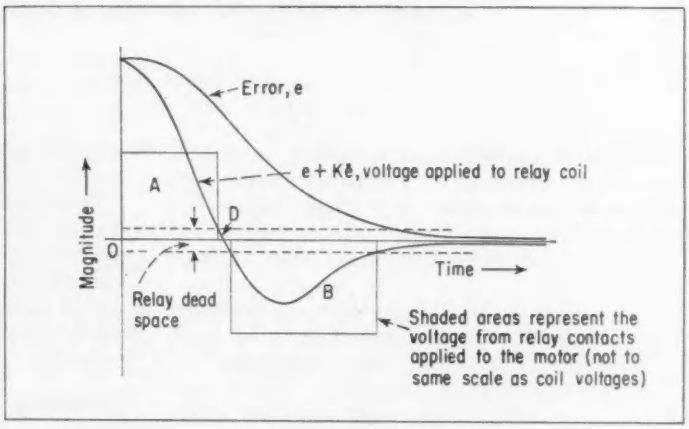


FIG. 3. Relay coil and current voltages.

measurements indicated an inductance of 0.75 henries per coil with a response time of 0.715×10^{-3} sec after a step function of rated voltage was applied to one coil. This lag is negligible compared to the inherent time lag in servos with ratings of 1 hp or larger, and is still small compared to the lag in most smaller servos. For the majority of applications, switching done with a relay of this type will be satisfactory.

Computer theory and design

Figure 1 shows a block diagram of the computer. With a step input, the error signal for a system with no overshoot would usually appear as shown in Figure 2, curve A. To this signal is added the error rate signal with a variable amplitude. This latter signal, designated by $\dot{e}$ in Figures 1 and 2, is obtained by differentiating the error signal. The resultant is shown in Figure 2, curve *B*. Curve *C*, Figure 2, indicates the sum of e and $K\dot{e}$.

The voltage $e + K\dot{e}$ is then amplified and applied to the relay, which is energized by essentially a square wave of current, since the driving source saturates. The point of reversal, or the point where $e + K\dot{e}$ goes through zero, is roughly proportional

to K, so that the point at which the relay switches from one contact to the other can be controlled by varying the gain, K, of the error rate amplifier. The relay then supplies a saturation magnitude signal to the servo. An approximate representation of relay coil and contact voltages is shown in Figure 3. The shaded area marked A represents positive torque signal being applied to the system.

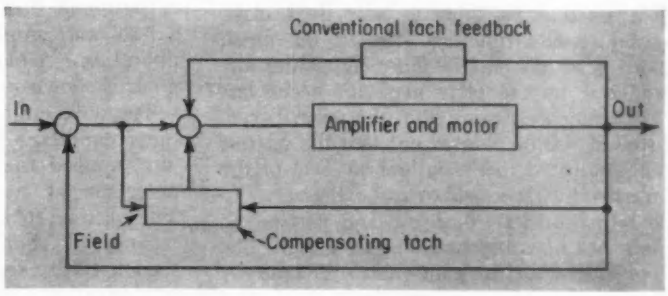
While signal A is being applied, the motor or drive element is driving the output as fast as possible in the direction to decrease error. At switching point D, determined by the error rate gain in the computer, the torque signal is reversed and the drive unit is decelerated uniformly until the error has reached such a magnitude that the relay drops out and remains in a neutral position. For error signals where $e + K\dot{e}$ lies within the dead space of the relay, no switching occurs and the system operates with proportional control.

Typical application

To clarify this explanation of computer function and to indicate the overall system operation, a typical second-order position servo, using the computer in dual-mode operation, will be examined. Figure 4 represents a block diagram of the complete system.

For a step input, the error immediately rises and the relay switches to supply positive torque signal A, as shown in Figure 3. This signal, of saturation

EVOLUTION OF THE DUAL-MODE TECHNIQUE



Block diagram of Lewis nonlinear damping method.

One of the first uses of nonlinear damping was described by Lewis[1] in 1952. His system is shown in the accompanying figure. For relatively large errors, the signal applied to the field of the compensating tachometer is high, and consequently, compensating tachometer output is very large compared to the normal tachometer feedback. It thus adds to the error to speed the output towards zero error. As the error gets smaller, output of the compensating tachometer decreases. And as it approaches zero, normal tachometer feedback effectively increases system damping. It then becomes possible to add more gain so that system response is improved without upsetting the system stability. In effect, the above combination produces variable damping. For large signals, the damping is very low, giving fast response characteristics; for small signals, damping is increased to reduce the occurrence of overshoot. Thus, this type of compensation aids transient response and may improve steady-state operation. From this basic system, similar compensating circuits have been developed, replacing the tachometer with tubes or other circuit elements.

Another interesting type of nonlinear compensation is "multiple-mode" operation, introduced by McDonald.[2] This type of operation implies two or more distinct modes of operation, depending on error and error rates and servo parameters. Of special interest is the dual-mode operation described in this article and discussed in the Cook Technical Report No. T16,1.[3]

magnitude, is applied to the amplifier, completely overcoming the normal feedback and tachometer feedback. As soon as the error decreases to a value near one-half its maximum, the relay operates to reverse the signal. The actual point of switching is controlled by the gain in the error-rate amplifier and depends on the particular system involved.

In a practical situation this gain is adjusted until no overshoot occurs when the system is energized with a step input of large magnitude. The reverse signal decelerates the drive member so as to reduce the error as fast as possible without causing overshoot. When the error has dropped to such a magnitude that the voltage representing $e + K\dot{e}$ no longer is sufficient to operate the relay, the contacts open and remain open until another large error signal occurs. When the relay drops out, normal continuous control is resumed with the tachometer providing high damping. This permits increased stiffness and stability at low errors or error rates. If the servo is well damped in some other manner, the tachometer may be omitted altogether.

In an attempt to compensate a small ac instrument servo with this computer little improvement in operation was noted. There are several reasons for this:

(1) Most small servos operate near their maximum capability, with time lags that are not much longer than those inherent in the relay. Thus, any signal produced by the relay may not occur fast enough to be much different from the normal feedback. It should also be pointed out that the relative error signal compared to the saturation level of the servo is usually high enough to cause the servo to operate at saturation level during a large part of the error signal, with no compensation whatsoever. The problem of overshoot is somewhat overcome by merely using tachometer feedback.

(2) A demodulator must be used in an ac servo application to provide only the error envelope to the computer. The time delay in most present-day demodulators is relatively high compared to the delay in the small servo. This is probably the most significant disadvantage encountered in attempting to compensate ac instrument-size servos with the computer-relay-tachometer combination. If a delay-free demodulator could be built, the application area of dual-mode compensation could be extended to take in many of the smaller ac servos which at present gain nothing from attempted compensation.

(3) The important limiting factor in the computer-relay combination is the time lag in the relay. As mentioned above, the contacts do not close until 0.715×10^{-3} sec after the voltage is applied to the coil. For some small servos, this lag would be very significant compared to the uncompensated error signal duration, and compensation could only be obtained with a faster acting relay or a vacuum-tube switching circuit. Despite limited use of dual-mode compensation in very small servos, there exists a wide range of application in larger servo systems, both ac and dc. It is especially well adapted to dc types, as a series of tests on a medium-size dc positioning-type servo has shown.

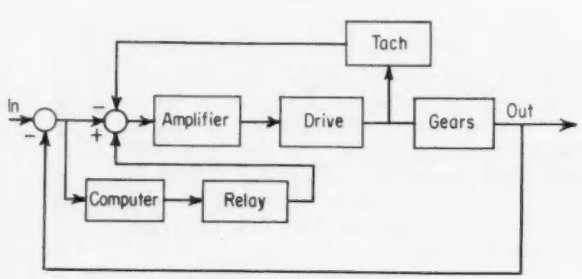


FIG. 4. Block diagram of relay compensation for typical second-order position-type servo.

Test procedure on a dc position-type servo

To further investigate the advantages of this nonlinear compensation, an experimental 1-hp dc position-type servo was constructed. The driver unit of this servo was a Westinghouse 1-hp shunt-wound motor coupled to a 40:1 anti-backlash gear reducer. A push-pull 6AS7 vacuum tube amplifier driving a 1,000-watt amplidyne provided the necessary amplification. A block diagram of the servo and computer is shown in Figure 5.

The servo error, appearing at point e, was fed into the computer. A saturating voltage of 22½ volts was supplied to the relay contacts, and the computer output connected to the amplidyne input. The vacuum-tube amplifier was by-passed for two reasons: (1) Since the tube saturates long before the amplidyne, the amplidyne would never be driven into saturation and its maximum performance would not be obtained; (2) it is much easier to obtain power gain through the relay than with a tube amplifier. With the connections described above, the relay handles the large saturating currents needed when the error is large, while the amplifier is sufficient to handle low error signals and those that vary slowly.

With this system in operation, recordings were made of performance characteristics, with and without compensation. Several of these recordings are shown in Figure 6. All were taken with a peak-to-peak input of 25 volts supplied by a function generator. An examination of this data and the testing procedure involved showed that:

- the computer cuts the response time to a step input down to nearly one-fourth that of an uncompensated system
- by proper adjustment of the relay switching time (point *D*, Figure 3) system overshoot can be completely eliminated
- response to low-frequency steady-state disturbances has been greatly improved; this is indicated in Fig-

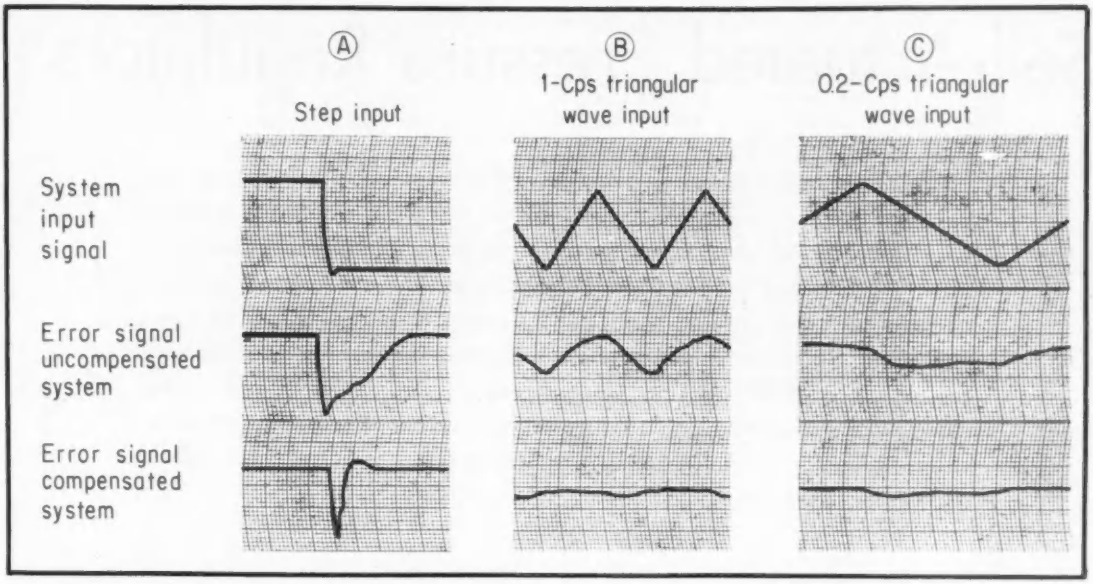


FIG. 6. Performance curves for three types of input signals.

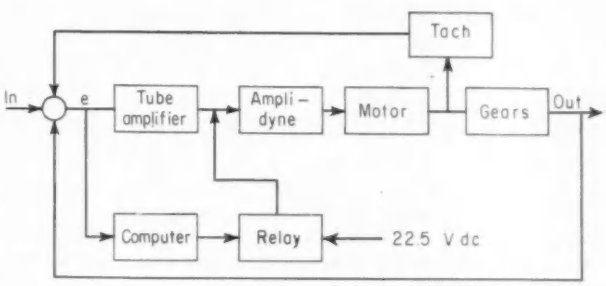


FIG. 5. Relay compensation of dc position-type servo.

ures 6A and 6B, in which the difference in error signals can be clearly seen

• above $f = 2$ cps, the compensator fails to help the steady-state response; at these frequencies, however, the servo itself has poor performance characteristics.

Conclusions

This computer-relay combination demonstrates the successful application of nonlinear compensation to servomechanisms. The method involves a simple, relatively inexpensive computer plus a fast-acting relay. Experimental results indicate the improvements that can be made in position type servos with a dual-mode operation. For systems that must follow step inputs or rapidly changing inputs, the computer-relay can improve response by as much as 400 percent. The proportional control for low errors or error rates gives the system greater accuracy and stiffness, while the relay control assures fast response for larger signals. As was the case in the experimental setup, some components of the servo amplifier need not be of great power capacity since large amounts of power may be obtained through the relay. Low-power elements in the system need only respond to low errors and maintain proportional control for small signals.

Elimination of steady-state errors due to friction and tachometer feedback might well be the subject of future investigations. Triple or quadruple-mode operation should also be studied. It may be that higher modes of operation could compensate for steady-state error induced by normal tach feedback.

Acknowledgment

Most of the research reported above was carried out at the University of Utah and sponsored by the U. S. Signal Corps Laboratories under contract with the EE Dept.

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Self-Actuated Pressure Regulators

THE GIST: Simple, fast responding, easy to maintain, and low in cost, self-actuated pressure regulators are suitable as moderately accurate pressure controllers. Satisfactory operation on installation requires knowledge of their functional and constructional characteristics. These the author explains, not as a review of catalog types, but by giving a clear definition of basic variations. His major emphasis is on application information; he discusses the effects of fluid velocity, point-of-pressure-measurement, and spring elongation, and warns against full reliance on catalog ratings of these valves without an understanding of rating-test conditions and actual application conditions.

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A self-actuating regulating valve automatically controls a process variable using only the fluid in the pipe as the actuating medium. That is, the force needed to move the valve plug is obtained directly from the fluid controlled by the valve. Such valves are classified according to construction and function. Constructional variations are: direct-actuated regulators of the diaphragm, piston, and seat-loaded types, pilot-operated regulators, and aspirating regulators. Functional variations are: reducing, back pressure (relief), differential (reducing and relief), and safety (seat-loaded relief) types. The accompanying table elaborates on these features.

The seat-loaded relief valve, Figure 1, is a commonly used self-actuated valve. Here, the valve opens when the force of the pressure difference (inlet pressure minus outlet pressure) multiplied by the valve seat area exceeds the opposing spring force. Technically, then, such valves are differential valves, but in most applications the outlet pressure is atmospheric so that the relief valve is generally considered as a fixed pressure valve.

Reducing valves

A typical application of self-operating valves is in reducing the pressure of cold water from 40 psi to a nominal 10 psi outlet pressure. A 1-psi variation is specified. That is, an outlet pressure droop from 10 to 9 psi is acceptable. The reducing regulating valve, Figure 2, can be considered for this application. It consists of a valve body, a valve plug and stem, a spring, a diaphragm, and an ex-

FEATURES OF SELF-ACTUATING PRESSURE REGULATORS

CONSTRUCTION

- A direct-operated regulating valve imposes the controlled pressure on its diaphragm or piston, which is rigidly connected to and positions a valve plug.
- A pilot-operated regulating valve imposes the controlled pressure on the diaphragm of a pilot valve. The pilot valve then regulates the fluid pressure imposed on the main valve diaphragm that directly positions the valve plug.
- A seat-loaded regulating valve has no diaphragm. The valve's spring-loading force is balanced directly against the force created by the valve's pressure drop on the valve-plug area.

FUNCTION

- A reducing valve measures and regulates **downstream** pressure regardless of variations in inlet pressure or flow demand. A reducing valve closes as its **downstream** pressure increases.
- A back-pressure valve (relief valve) measures and regulates **upstream** pressure regardless of variations in outlet pressure or flow demand. A back-pressure valve opens as its **upstream** pressure increases.
- A differential pressure valve measures two pressures and maintains a constant difference between them. A reducing-type differential valve controls its own outlet pressure with respect to a reference-pressure variation. A relief-type differential valve controls its own inlet pressure with respect to a reference-pressure variation.
- A safety valve is, in general, a seat-loaded relief valve that opens fully before an unsafe pressure is reached. The valve dumps as much fluid as possible, for safety's sake, even though the inlet pressure drops considerably below the preset pressure before the valve closes again.

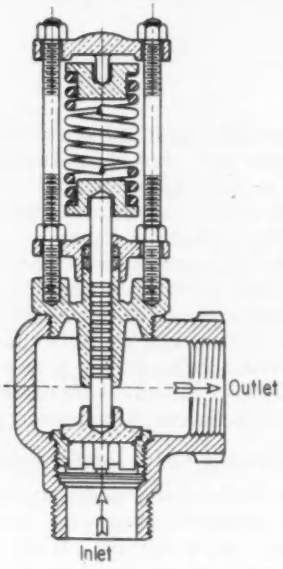


FIG. 1. Seat-loaded relief regulator.

ternal line that senses the downstream pressure. This valve, then, is a direct-operated diaphragm-type reducing valve, reducing because it regulates the downstream pressure. Assume the valve size is 1 in., the diameter of both valve seats is ¾ in., and the effective diaphragm area is 57 sq in. Figure 3 shows the outlet (downstream) pressure vs. flow-demand characteristic for such a valve at a constant 40-psi upstream pressure.

The valve plug positions to a state of equilibrium when the force pushing the valve stem downward equals the spring compression force pushing the valve stem upward. The downward force equals the downstream pressure, as sensed by the external line and applied to the diaphragm, multiplied by the effective diaphragm area.

When the flow demand is zero (fully closed downstream faucet) the downstream pressure (from Figure 3) is the nominal 10 psi. The force pushing down on the valve stem is 10 psi times 57 sq in., or 570 lb. The spring pushing up is 6 in. long when the valve is closed and has a compression force of 570 lb. However, the spring force reduces 11.5 lb for every 0.01-in. elongation of the spring.

Suppose now the faucet is opened slightly to demand a flow of 6.7 gpm. The force pushing the diaphragm and valve stem downward decreases and the spring pushes upward. The valve opens slightly and the spring force decreases as the spring elongates. Eventually, a new equilibrium position is reached: outlet pressure drops to 9.8 psi at 6.7 gpm, as shown in Figure 3. This results in a downward thrust of 558.5 lb (9.8 psi x 57 sq in.). The spring, now 6.01 in. long, produces an upward force of 558.5 lb.

Figure 3 shows the outlet pressure that establishes position equilibrium for various flow rates. The regulating valve exhibits the droop that is characteristic of regulating devices. This particular valve regulates flow satisfactorily up to 34 gpm, at which point the outlet pressure reaches the minimum acceptable value of 9 psi. A bigger valve must be used for larger flow rates so that the same valve lift will result in a larger port opening and hence more flow.

The spring force establishes the nominal outlet pressure (the regulator's set-point), but as the flow increases the spring's elongation shifts this point. Too much elongation reduces the outlet pressure below its permissible pressure variation. Keeping the elongation small means keeping the valve lift small. One drawback to the simple regulating valve of the type so far described is that small lifts limit the valve's flow capacity. This situation is quite different from the common diaphragm-motor valves, in which a small change in the controlled variable is amplified by a controller into a 3-to-15-psi air-pressure signal. This big change in air pressure on the diaphragm motor can compress the spring

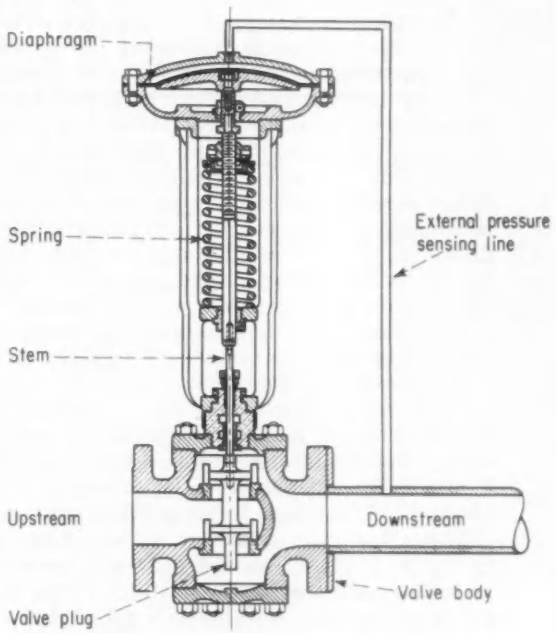


FIG. 2. Direct-acting diaphragm-type reducing regulator.

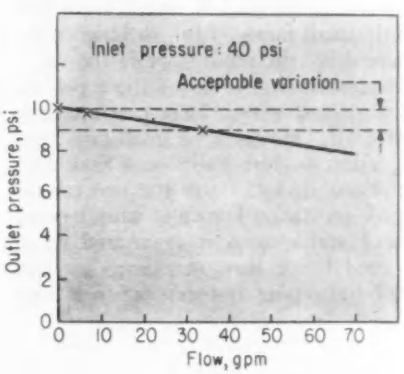


FIG. 3. Typical flow characteristic for a simple pressure-reducing regulator. The inlet pressure is a constant 40 psi, but as flow increases the characteristic droops because of shifting set-point due to spring elongation. L

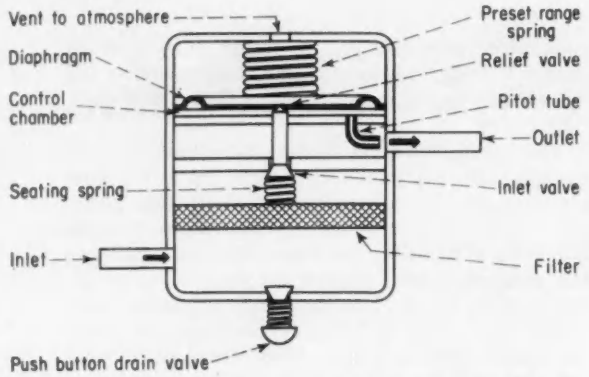


FIG. 4. Pitot-tube aspirating-type self-actuated pressure regulator.

fully to lift the valve through its long stroke.

Self-actuated regulators use beveled valve seats to get maximum flow capacity with small valve lift and small delivery-pressure variation. Beveled seats are not suitable for externally-actuated valves, which may require characterized parabolic or V-shaped ports, but they are acceptable in self-actuated valves because of the rapid and direct way pressure changes are communicated to the valve diaphragm.

This instantaneous response offers the advantages of fast pressure control and great rangeability without hunting. Consider the control of a motor-driven oil pump whose discharge pressure is regulated by a self-actuated diaphragm-type relief valve. When the switch is closed at pump startup, the pressure rises almost instantaneously to valve's set-point. The valve then opens and regulates at this value without any appreciable overshoot.

Controlled-pressure magnitude is an important consideration in selecting self-actuating reducing valves. For the valve described in connection with Figure 3, the variation in outlet pressure of 1 psi (from 10 psi nominal to acceptable 9 psi) is 10 percent. However, if this same valve were used to regulate 150 psi nominal delivery pressure the 10 percent variation (same valve lift) would be 15 psi, which for many applications is not good enough control for the desired flow range. Conclusions: the lower the pressure setting the more suitable the self-actuating reducing regulator appears to be. When this type of regulator must be used for high-delivery-pressure work it requires a large spring force, and hence it must be limited to small valve lifts and consequently small flows. Also, the higher the available pressure drop, the more suitable the valve.

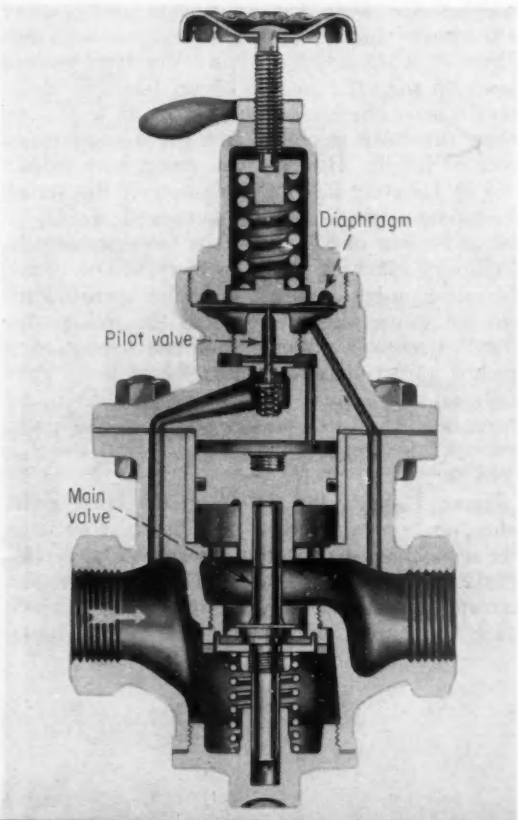
Self-actuated pressure regulators of the types described so far work best with a large pressure drop and a small valve lift. However, at small flow rates the valve plug rides so close to its seat that after a few weeks of handling wet steam the seat can be severely damaged, a situation known as wire drawing or erosion. Such seat erosion is aggravated when the piping is sized larger than necessary, because, though more of the piping system's pressure drop is concentrated in the valve, the valve lift is reduced. In the past, valve manufacturers compensated for the reduced valve lift, with its attendant seat erosion, by reducing seat diameter; this required a larger lift for a given flow rate.

As engineers became more knowledgable about calculating flows and designing piping systems they made the pipes just big enough for flow demand and provided pressure headers so that process loads could be served without a big pressure drop in the valve. But then small-seated regulators became inadequate for high-capacity, low-pressure drop applications.

Improving valve performance

With increased understanding of the flow control problem, valves have been designed to give greater valve opening, small variation in delivery pressure, and smaller pressure drop. The two basic innovations for improving valve performance are the aspirating effect and pilot-valve operation. Figure 4 shows a type of aspirating valve in which the effect is created by a pitot tube. The fluid passes through the outlet end of the valve at high velocity and creates suction underneath the valve diaphragm. This reduces the pressure in the control chamber to something less than the pressure in the outlet pipe. The effect makes the diaphragm "think" the outlet pressure is decreasing so that the spring moves the diaphragm downward and increases the valve opening, thereby permitting more flow at the same delivery pressure in the outlet pipe. This pressure-faking under the diaphragm compensates for spring

FIG. 5. Pilot-operated reducing-type pressure regulator.



delivery pressure regardless of flow-demand variation. elongation, and the valve holds relatively-constant

The other popular method of obtaining a large valve opening is with the pilot-operated valve shown in Figure 5. The pilot-valve diaphragm senses the downstream pressure and a downward movement opens the pilot valve to admit inlet pressure into the space above the piston faster than pressure leaks past the piston ring. This creates a differential pressure across the piston, pushing it downward to open the main valve. The main valve reaches equilibrium position when the pilot valve throttles the pilot flow just enough for the delivery pressure on the diaphragm to balance the spring setting.

The pilot valve's full travel and the spring's elongation are both only several thousandths of an inch. But the main valve moves through a long stroke permitting a large flow range without significant pressure variation because of spring elongation.

Differential-pressure valves

A self-operated differential-pressure regulator maintains a controlled pressure relative to some reference pressure introduced in its spring chamber. The valve maintains its controlled pressure equal to the reference pressure plus (or minus) the equivalent spring value. As the reference pressure varies, so does the controlled pressure.

Differential reducing valves are widely used with steam-atomizing oil burners. Here, it is desired to keep steam pressure for atomizing fuel oil at a fixed differential above the fuel-oil pressure. The circuit is shown in Figure 6. While the fuel-oil pressure varies with a change in fuel flow (combustion rate), the pressure of the atomizing steam stays at a fixed differential above the fuel pressure, thus giving proper atomization at all combustion rates.

Differential relief valves are frequently used to maintain sealing oil in gland seals 10 to 25 psi higher than gas pressure in pipeline compressors to prevent leakage of the gas through the seal. As shown in Figure 7, the differential relief valve relieves the positive-displacement oil-pump discharge pressure back to the reservoir just sufficiently to maintain the oil at the desired differential above the gas pressure (which may reach 1,000 psi) in the casing.

Application tips

An important consideration in applying and sizing self-operated pressure-regulating valves is the effect of the fluid's velocity on the valve's accuracy and regulation capability. This effect differs considerably for valves having external sensing lines, such as in Figure 3, and valves having self-contained sensing passages or pipes, such as in Figure 4.

The self-contained valve responds to the pressure in the valve body, but what is desired is control of pressure at the valve outlet or at some downstream point. The restriction between the valve body and the outlet introduces a pressure drop, variable with

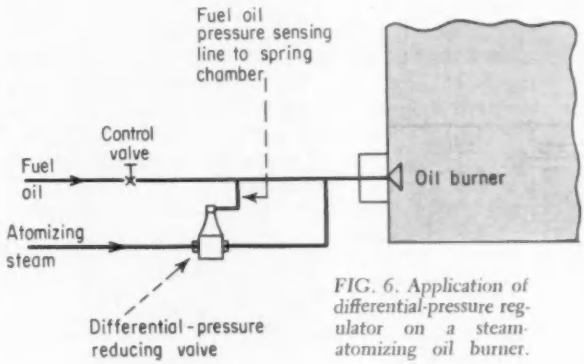


FIG. 6. Application of differential-pressure regulator on a steam-atomizing oil burner.

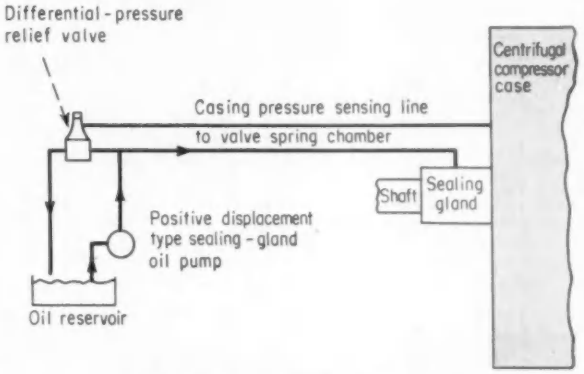


FIG. 7. Application of differential-pressure regulator to prevent gas leakage through the gland seal on a high-pressure gas compressor.

flow rate (velocity), that creates an error between the desired and actual pressure at valve outlet. A large error occurs at maximum flow and a small error at minimum flow. Therefore, it is necessary to limit the velocity in the valve outlet to a value that will assure acceptable resulting pressure drop over the flow range. In general, acceptable maximum velocity values for self-contained valves are about 20,000 ft per min for steam and gases and 15 ft per sec for water.

In sizing self-contained, self-operated reducing valves for relatively large pressure drop applications (reducing steam or gas pressure from 100 to 5 psi) the first step is to obtain the size on the basis of Cv. Then check the velocity tables to make sure the selected valve size does not exceed velocity limitations. If it does, select a larger valve that meets an acceptable velocity. (Downstream piping must be sized according to good piping practice, and not based on valve size.) Oversizing is no disadvantage (except as to cost), provided the seats are hard enough to withstand erosion, because direct-operated valves provide great rangeability.

The velocity effect is not so critical for valves with

external sensing lines, that regulate pressure almost independently of the pressure drop between the valve body and the point of connection to the sensing line. The velocity's effect on the allowable pressure drop and on valve sizing is determined by the critical pressure. A valve is basically an orifice. As outlet pressure decreases below inlet pressure, the flow increases continuously to the critical pressure. Then flow remains constant as the outlet

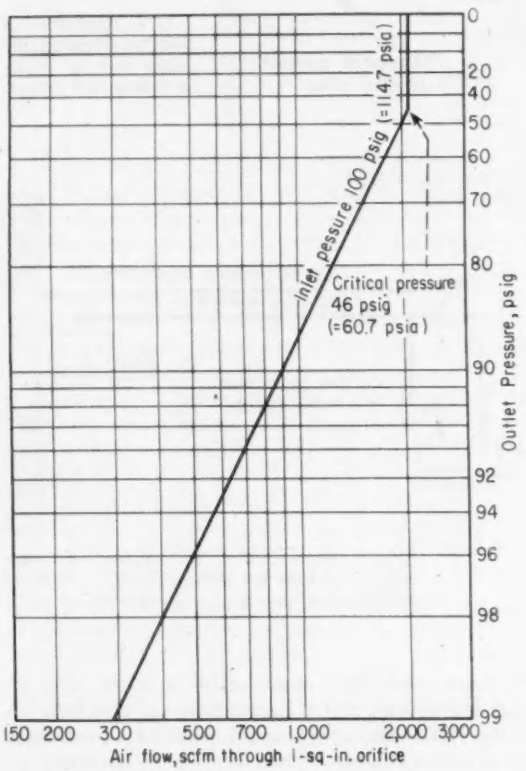


FIG. 8. Flow remains constant when outlet pressure decreases below critical pressure.

pressure decreases further. In general, critical pressure ranges from 50 to 60 percent of inlet *absolute* pressure, depending on the fluid: for air it is 53 percent; for steam it is approximately 60 percent. The critical pressure effect is typified in Figure 8.

Consider a valve to reduce air from 100 psig inlet pressure to 5 psig outlet pressure. From Figure 8, the critical pressure is 46 psig. The flow through the valve opening is the same for an outlet pressure of 46 psig as it is for 5 psig. Therefore, a pressure drop of 41 psi, from valve body to point of delivery measurement, is permissible without affecting valve sizing. The rule-of-thumb for valves with external sensing lines is to check the outlet velocity for a particular valve size at critical pressure (46 psig, even though the controlled pressure is actually 5 psig), and make sure this velocity does not exceed 30,000 ft per min.

One disadvantage of the self-contained valve, as just discussed, is the lower permissible velocity. Advantages are simplified piping and reduced installation cost. A disadvantage of the external sensing line is that the fluid is substantially motionless and subject to freezing or hardening.

The accuracy of self-operating pressure regulators can be generalized from some typical applications:

- small (½-in.) high-pressure reducing valves, such as for controlling pressure in hydraulic systems, can drop a pressure from 2,000 psi to 500 psi and maintain it within 25 psi variation at rated capacity
- small- and medium-size reducing valves, such as for reducing steam or gas pressures from 100 psi to 15 psi, can maintain the pressure within ¼-psi
- large pilot-operated valves can reduce pressure from 150 psi to 125 psi and maintain it within 2 psi
- gas-pressure regulators can reduce pressures from 10 psi to 6-in. water-column and maintain pressure within ¾-in. water-column variation
- a relief valve, such as that used with pumps handling bunker C fuel oil, maintains back pressure at 300 psi; variation is within 10 psi

Two important things to consider in installation are safety and valve location. Self-operated pressure regulators do not fail safe in case of diaphragm rupture: reducing valves open wide and back pressure (relief) valves close. But though diaphragm rupture is infrequent, it is advisable to install in the system a safety valve, set at a pressure just higher than that of the regulating valve.

Sometimes regulating valves are used with steam lines that "pitch down" to the valve. That is, the valve has a lower elevation than the lines. Condensate will form at the inlet if the valve operates in a closed or nearly closed position for any length of time. When it opens the condensate rushes through with steam and erodes the seat rings, plugs, and even the valve body. A condensate trap installed at the inlet will drain this water and reduce the wear and tear.

Catalog ratings

Valve ratings given in catalogs frequently are based on tests that are not equivalent to conditions actually existing on installation. The instrument engineer should consider these factors when using catalog ratings:

- controlled-pressure droop—valve capacity may be rated at such a large pressure droop that controlled pressure drops to below an acceptable variation.
- outlet velocity—valve capacity may be rated at such a large outlet velocity that excessive pressure drop will result at the valve outlet.
- pressure-measuring point—valve capacity may be based on pressure measured in the valve body, but the user is interested in capacity based on pressure at the valve outlet or at some downstream point.

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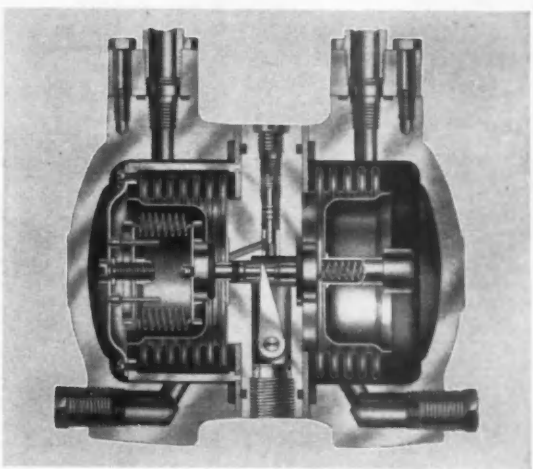

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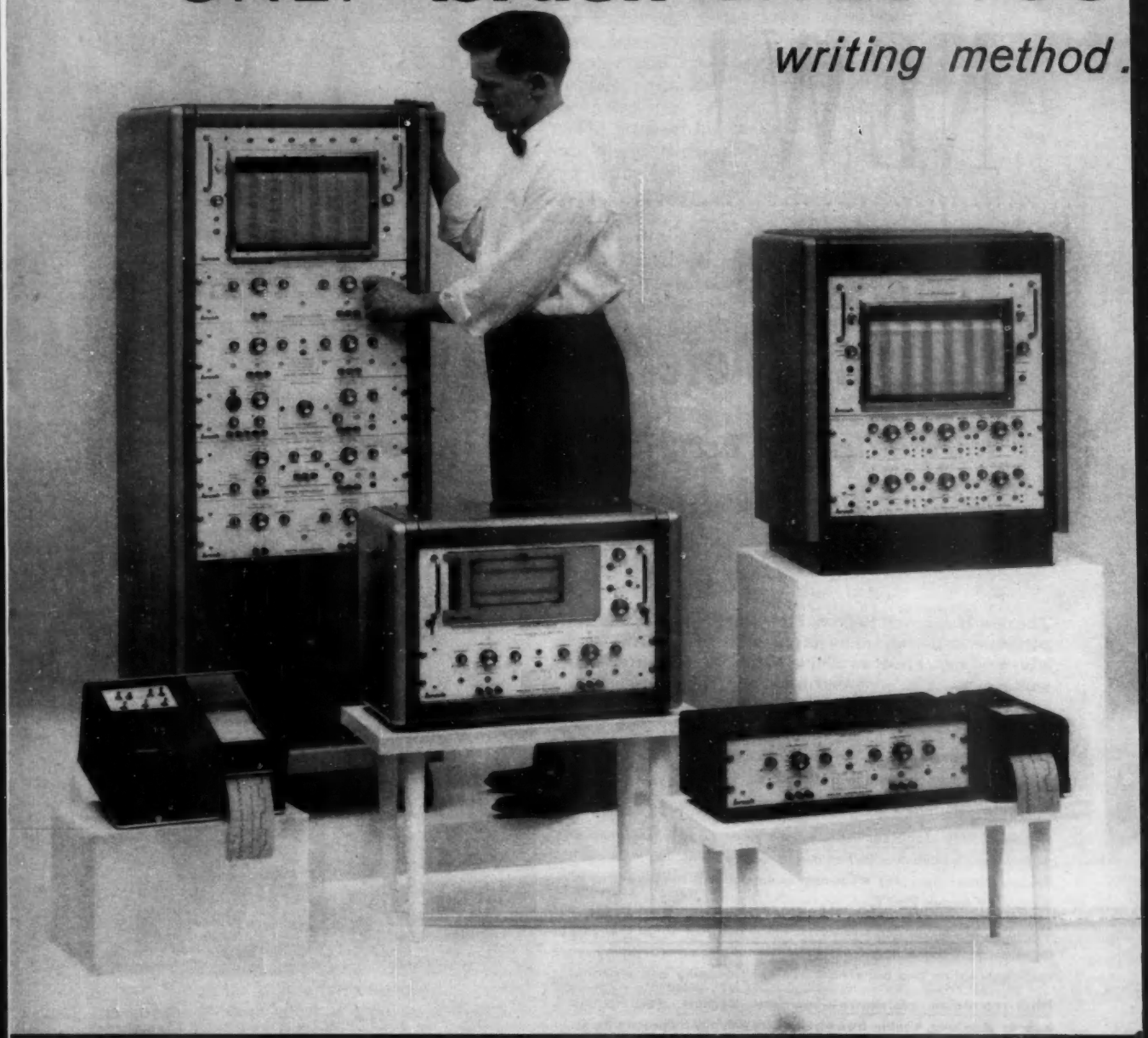

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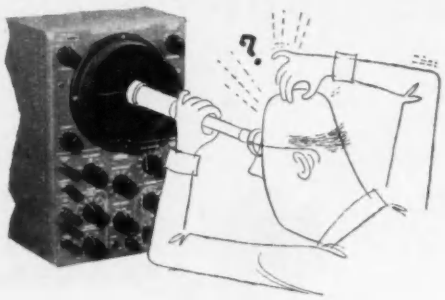

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Counting is Still Computing

CHARLES STORIE, Computer Measurements Corp.

Expensive special computing equipment can sometimes be obviated by manipulating the equations so that more basic operations, such as counting, will do what's needed. Here's an example.

Measurement problems which would seem at first glance to require computation sometimes can be reduced to simple counting problems. Such simplification can make the difference between an economically impractical solution and a practical one. Consumer product and service industries, for example, often operate on the basis of fractions of a cent per unit product or service, and minute reductions in production costs can be very important.

Here is how an old problem in the commercial laundry industry was solved in a new way by simplifying computing control to counting control. The problem is that of folding pieces of assorted length, such as bath towels, hand towels, pillow slips, napkins, etc., after they have been ironed. Each piece must first be folded lengthwise exactly in half, which implies that the center of the piece must be located rather exactly. In folding by hand, the center of a towel is found by aligning the two ends. But because human folders have difficulty keeping up with the ironers, the production rate or quality of folding must suffer.

An automatic folding mechanism uses the principle shown in Figure 1: a folding knife presses the center of the towel between two counter-rotating conveyor rolls, and the rolls then draw the towel between the conveyor belts, which carry it, folded at the center, to the sorters. Production rate is limited primarily by the speed with which the towels can be drawn between the rolls. Alignment of the free ends of the towel depends on how well the exact center of the towel has been located, making this location the problem to be solved.

Assorted lengths complicate solution

If all the towels to be folded are of the same length, the solution is extremely simple; it is shown in Figure 1. A photocell or some type of contact placed one-half towel-length beyond the rolls can detect the leading edge of the towel and actuate the folding knife. Once the towel length is measured, during machine setup, the photocell is positioned permanently. No length measurement need be made each time a towel is folded.

If towels (or other pieces) of mixed lengths are to be folded, however, each towel must be measured individually and its center determined. At first glance, this would seem to be a computing problem; certainly, the system of Figure 2 will do the job.

In Figure 2, a toothed wheel and magnetic pickup are used to generate a series of pulses—N pulses per inch of conveyor belt travel. A photocell located X inches ahead of the folding gap turns on a binary counter when the leading edge of the towel passes. If the towel is L inches long, the center of the towel will be at the folding gap when the leading edge of the towel has passed the gap by $L/2$ inches. The total count (C) in the counter at that time would be:

$$C = NL + N(X - L) + NL/2$$

where

NL = count required for the length of the towel to pass under the photocell

$N(X - L)$ = count required for the leading edge to travel the remaining distance to the folding gap

$NL/2$ = count required for the leading edge to travel $L/2$ in. beyond the folding gap

This equation simplifies to

$$C = NX + NL/2$$

Thus the computer must take the count NL, divide it by 2, add the constant NX, and produce a knife-actuating signal when the total count equals C. Note that C is a variable that depends on towel length L. C must be compared to the actual count to generate an actuate signal.

Counting simplifies control

An ingenious simplification of this knife actuation control was formed by Eugene Hajos of the Zephyr Laundry Machinery Co., who resolved the computation of C to a counting process. Consider what happens if the counter counts at N pulses per inch while the towel is passing beneath the photocell,

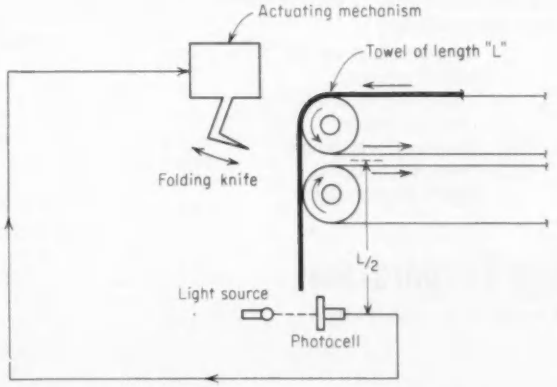
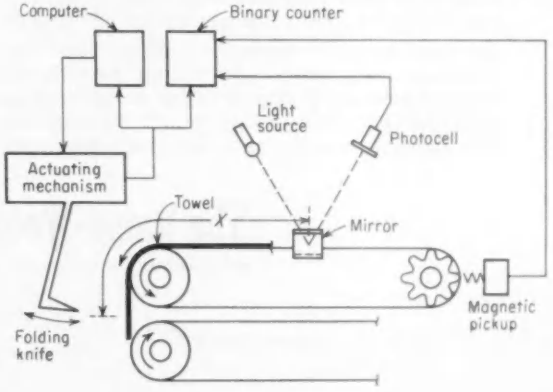
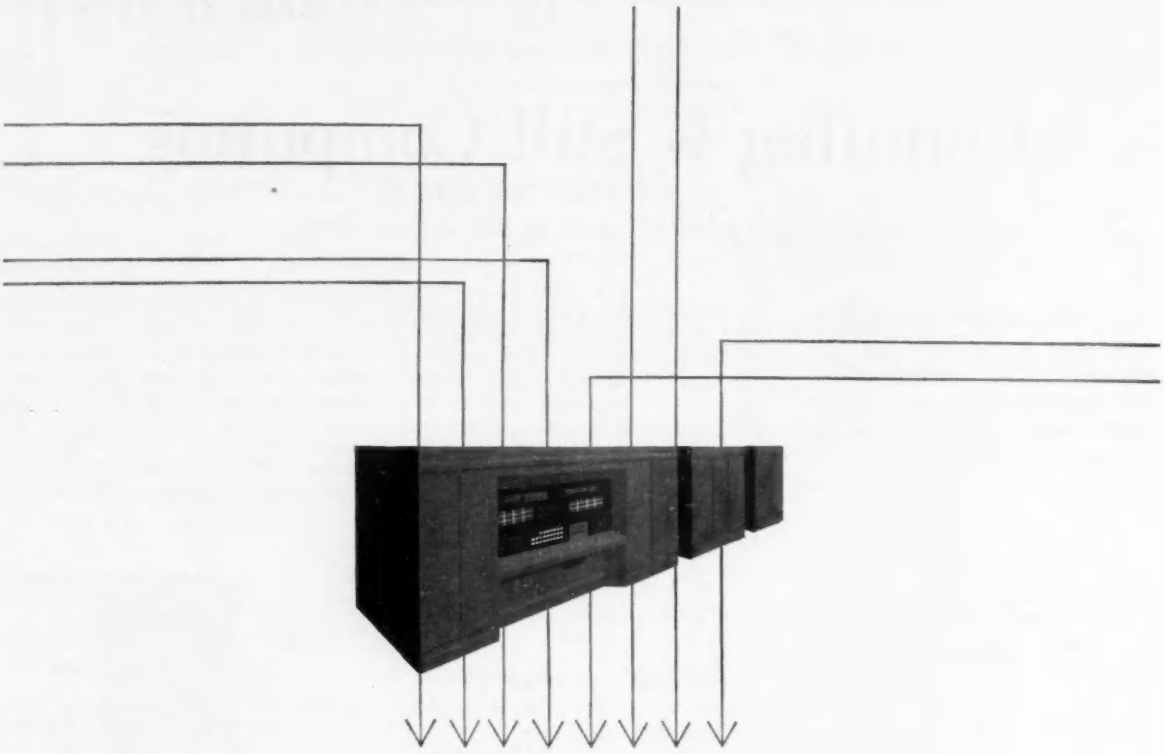


FIG. 1. Automatic towel folder draws towel, center first, between two conveyor belts. Control system for equal length towels is simple.

FIG. 2. Computing control of folding knife will handle mixed towel lengths, but requires nonstandard, expensive computer.





The **ORGANIZATION** and **RETRIEVAL** of **INFORMATION**

The organization and retrieval of large volumes of diverse types of information is rapidly becoming one of today's more serious problems. Major areas where the problem exists include business and industry, the military, the government, and the scientific and engineering community itself.

In its simpler forms, the problem may involve, for example, the automatic handling and analysis of business data such as payrolls, sales and manufacturing figures, insurance premiums, and other essentially statistical data. At the other extreme are certain complex military situations which require the concurrent interpretation, analysis, and integration on a very short time scale of data from a wide variety of sources, including field reports, photographs, news reports, estimates of industrial activity, and the like. In many of these situations, there is the additional requirement to translate the information from a foreign language into English.

The development in recent years of electronic data handling equipment is now making possible the practical solution of many of these problems. Such equipment has the capability to perform arithmetic operations, make decisions among alternatives, store and retrieve large quantities of information, and at high speed automatically perform long, complex sequences of operations.

At Ramo-Wooldridge, work is in progress on advanced information handling systems that are characterized by large volume and widely different forms of information, short time scales, and a variety of uses and users. The scope of the work includes the planning of systems and procedures, programming various types of data handling equipment, and formulation of requirements for new equipment. Research is also under way on the machine translation of foreign languages into English.

Engineers and scientists with experience in the following fields are invited to explore the wide range of openings now available:

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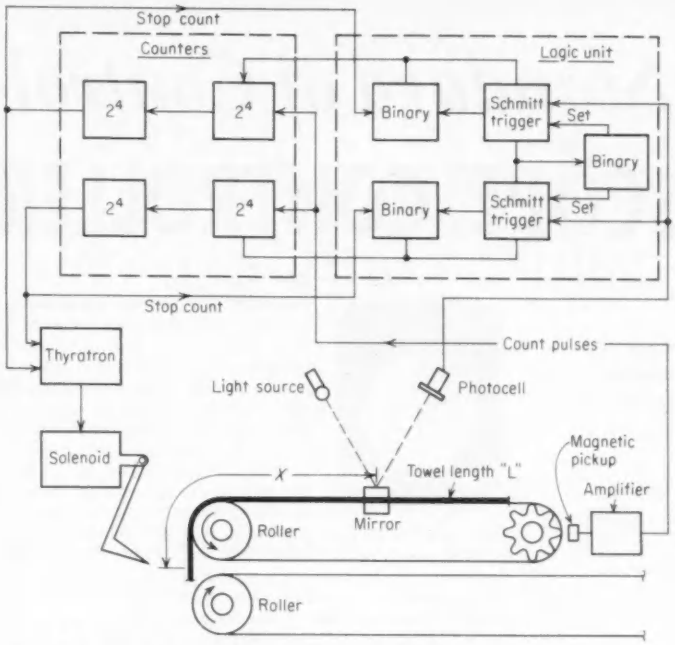


FIG. 3. This system simply counts, using off-the-shelf equipment. The logic unit does no computing.

but counts at $2N$ pulses per inch after the trailing edge passes. The equation for C becomes

$$C = NL + 2N\,(X - L) + 2NL/2$$

where the three terms are defined as before. This new equation reduces to

$$C = 2NX$$

which is a constant. The count for actuation of the folding knife is now independent of the length of the towel and can be made the limit of the counter's capacity, so that the counter produces the actuate pulse directly (see Figure 3).

A simple logic unit provides a bias signal to block the first stage of the counter after the trailing edge of the towel passes, causing the counter to count at the rate of $2N$ per inch.

Two counters, with a capacity each of $2^8 = 256$ counts, are used, one controlling one towel when a second towel triggers the photocell. This halves the necessary spacing between towels. The logic unit distributes control alternately to the two counters.

Preflight Calibration Makes Cards for Data Reduction

WILLIAM USIM
Lockheed Aircraft Corp.

In telemetering flight-test data from missiles, a number of measurement transducers frequency-modulate subcarrier oscillators which in turn modulate the telemeter transmitter. Like all other measuring instruments, the transducers must be calibrated before they are used, and this means that each one must be supplied with accurately known inputs.

An automatic telemetering calibration system has been built which checks the calibration of pressure and voltage transducers in their respective ranges and produces punched-card records of the calibrations.

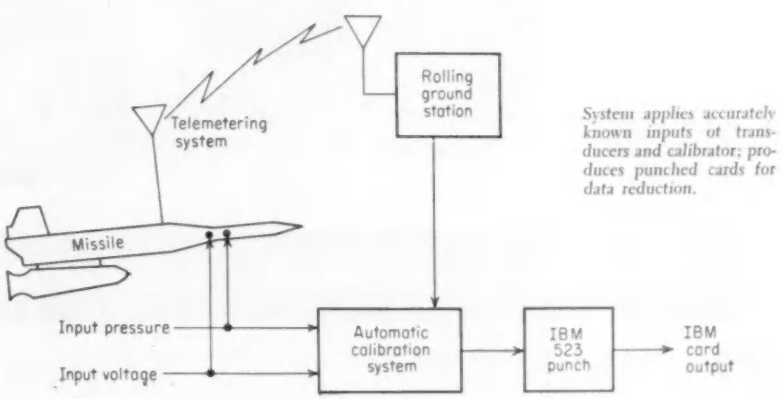
At the data-reduction station, in-flight data is converted to a digital count and punched into cards by an fm-to-digital conversion system designed by Lockheed. This data deck, along with the calibration deck, is used in an IBM 650 computer to obtain the actual data point solution. In-flight calibration points are compared to the pre-flight calibration data. The comparison indicates whether any changes have taken place in the telemetering circuits which would affect the accuracy of the original calibration data. Any necessary corrections are programmed into the computer.

The automatic calibration system is shown in a simplified block diagram form. It accepts the same accurate calibrating signals that are applied to the missile's transducers and applies them to carefully calibrated reference transducers. The outputs of both reference transducers and the outputs of the transducers being calibrated are recorded on a calibration card. Flight number; oscillator number, transducer number, operator, and date are recorded on the same punched card.

Note that the telemetering signal from the missile is normally demodulated into (subcarrier) tone signals by the "rolling ground station". Radio linkage is not actually required for calibration, however, since the composite telemetering signal is carried on two buses in the missile, and may be tapped there. But they may also bypass the rf transmission and reception, and replace the ground-station receiver output. In either case, the selected tone signal is applied to the automatic calibration system. The known input quantity and the corresponding subcarrier tone value are punched in cards. A card is punched for each value of the input quantity.

The reference pressure transducers used in the calibration system are Byron-Jackson "Vibrotrons", which are vibrating wire transducers that produce, directly, an output frequency inversely proportional to pressure. Eight Vibrotrons are used to cover the pressure range from 0 to 10 psia to 0-2,000 psia.

The voltage reference measurements are made by a Moseley Model 20 voltmeter with an accuracy of plus or minus 0.25 percent in any of 11 ranges between 0 to 3 millivolts and 0 to 300 volts.



System applies accurately known inputs of transducers and calibrator; produces punched cards for data reduction.

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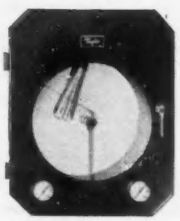

FULSCOPE RECORDING CONTROLLER is a versatile instrument for accurate recording and automatic control of one or two variables. It is completely adaptable to practically any control problem through the interchangeability of response forms: **Adjustable Sensitivity** for throttling control on applications with a wide range of time lags and capacities; **Automatic Reset** for precision control on applications involving a wide range of time lags and capacities, with gradual, sustained load changes; **Pre-Act*** derivative response for applications with a wide range of time lags and capacities, with sudden, momentary disturbances, but without sustained load changes. **Any combination of these responses may be had in single or double duty form.**

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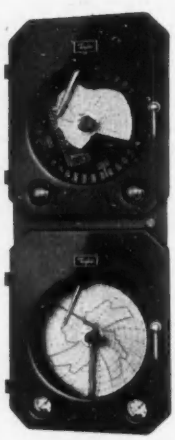

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Character Reading is a Signal / Noise Problem

C. E. G. BAILEY
The Solartron Electronics Group, Ltd.

Communication theory has it that signal-to-noise ratio can be improved as a signal is processed, by proper choice of the form of modulation which represents the signal. This concept has been put to work in one of the first practical machines for reading printed data.

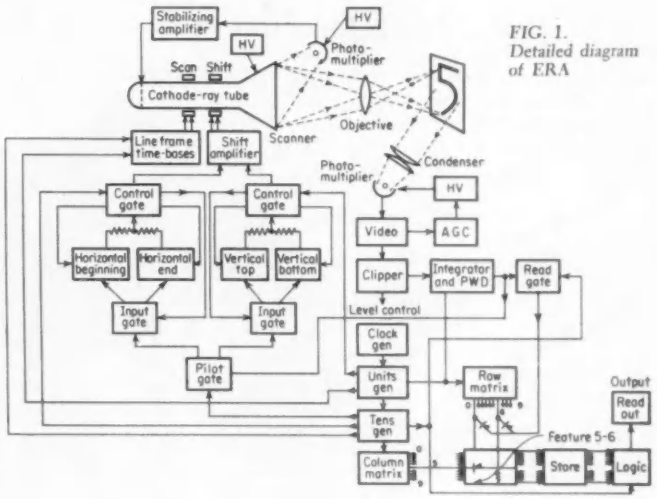

FIG. 1. Detailed diagram of ERA

The design of a character-recognizing machine can be considered a problem in signal-to-noise improvement. A page of blurred figures is the input. Any of these figures has a certain spatial distribution of black and white, but this distribution varies considerably between each sample of the same character. This random variation constitutes the "noise input". Noise in the output, however, can only be interpreted as the occasional misrecognition of a character; and this has to be reduced to as near an impossibility as statistics will allow.

To see how signal-to-noise improvement can be built in to a character-recognizing machine, consider the Solartron ERA (Electronic Reading Automaton). A flying-spot scanner covers each letter on the print with a raster, taking a few milliseconds for this process. The scattered light, high when blank paper is struck, low with print, is picked up by a photomultiplier and the resulting current amplified to a level convenient for processing. After passing through "clean-up circuits", it arrives at a store. So far all the information has been in a time series, and the object of the store is to allow parallel-channeling to take place. This is done by the preprogrammed "recognition logic", which sorts down the information to a yes-or-no decision on one line output per character, or alternatively to a time-series binary code.

Figure 1 shows the circuits in some detail. The scanning tube is fitted with a wideband feedback loop from luminous output directed at its face to control grid. This loop has a frequency response going down to dc and up to 1-megacycle order to reduce the "phosphor noise" caused by the finite size and unequal electroluminous efficiency of the phosphor. Uncorrected, this noise may approach the scattered-light signal level; and to let it go would be as unforgivable as to let a radio transmitter contribute significant noise to a transmitter-receiver chain.

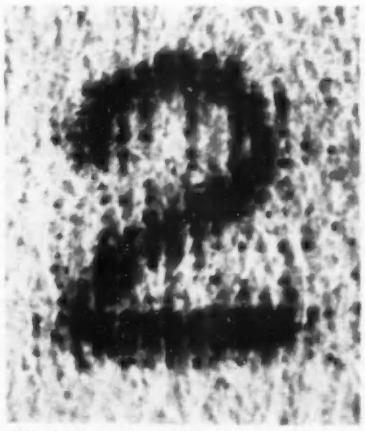

FIG. 2. Typewritten character shows "halo" of irrelevant dots which are recognized as "noise".

The scattered-light pickup is a photomultiplier, and delivers a signal at an amplitude suitable for processing.

Figure 2 is an enlargement of a typical character, and shows some of the random deviations from normal whose effect on correct interpretation has to be suppressed.

Signal/noise improvement

First, it will be seen that the paper is not uniformly white. (The type, by contrast, is much more nearly uniformly black.) The effect of this on a line scan is shown in the top trace of Figure 3. Simple clipping is used to get a clear black-or-white decision; the threshold has to be set automatically, with a manual override to suit the class of work.

Next, a certain amount can be done to clear up blurred characters. The apparent grey halo round these gets its appearance by something representing the half-tones in block printing, a congregation of quite black dots in an "offshore" area of white surrounding the mainland of the figure. The border of the figure is considerably cleaned up by applying pulse-width discrimination to the line scan. The middle and bottom traces of Figure 3

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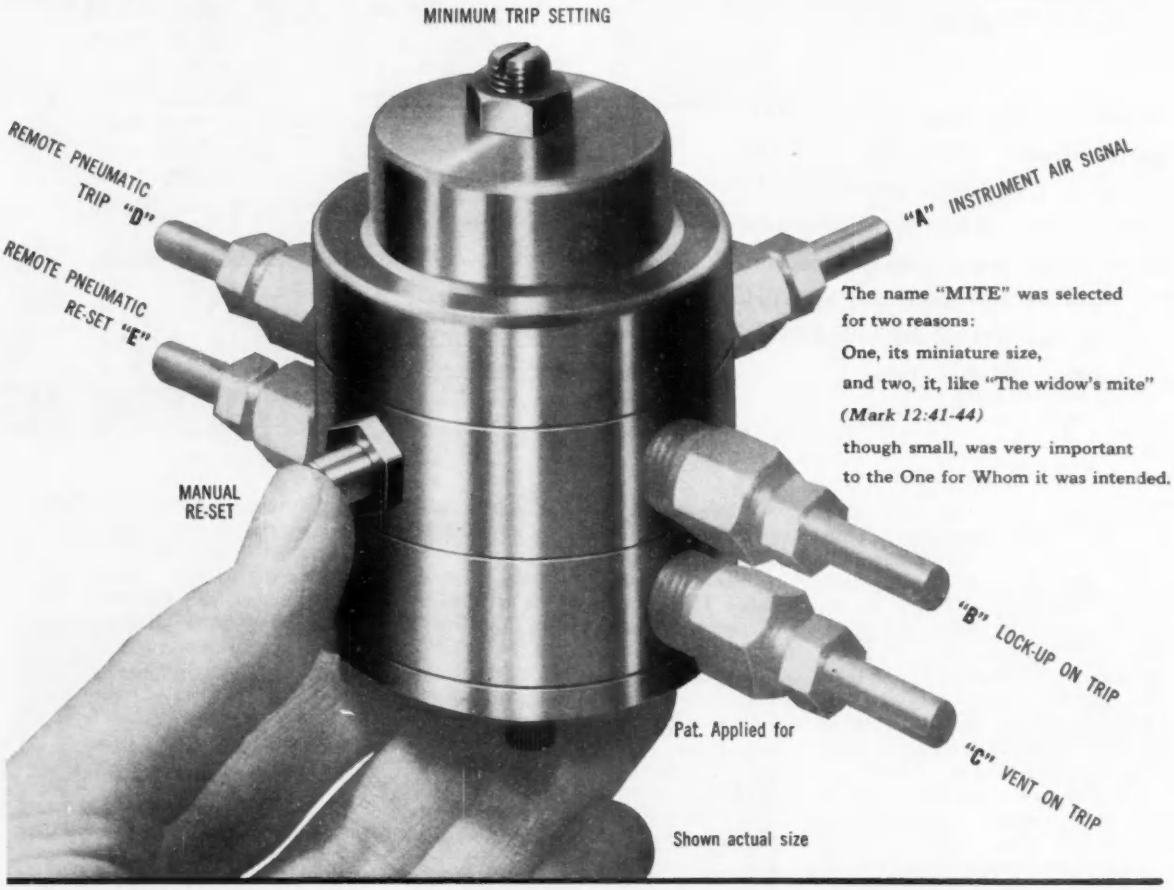

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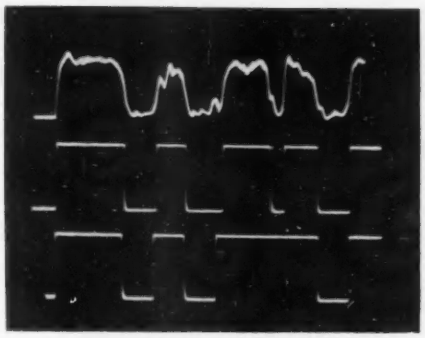

FIG. 3. Top line is signal from one line scan across character. Middle line shows sharpening possible by amplifying and clipping. Bottom shows how irrelevant noise can be reduced by pulse-width discrimination.

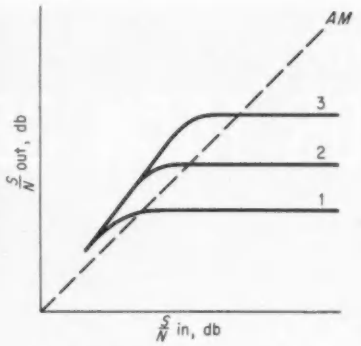

FIG. 4. Signal-to-noise ratios of some systems improve as ratio of input to output bandwidth increases.

indicate how one irrelevant black spot has been removed.

The finally cleaned and clipped raster is time-gated into "features", compared with permanently stored features of recognizable characters, and a definite black-or-white decision made for each of these features by a bistable circuit. The resulting features are stored in a temporary store—a convenient time-translation device to enable parallel operations to be done on the features. The operations are combinations of AND and OR logic in cascade.

The programming of the logical items, in the form of a block of connections, is quite complex. The principal organization of this process is that in which a number of features have an OR criterion applied to them, so that a black (say) in one will register as black for the group; then groups are connected with an AND criterion to impulse the output corresponding to a given character, when and only when all groups have the appropriate sign. Other more complex arrangements are superimposed, with some attention to those in which a final OR combination is used.

The principal characteristic of the store and logic, however, is that the information is condensed to the final minimum required by taking *combinations* of "bits" and comparing them by means of an assigned code. Thus the system bears a qualitative analogy to pulse-code modulation.

Modulation methods

A short digression is worthwhile here to summarize modulation methods used in communication, such as frequency-modulation, pulse-width and pulse-phase modulation, and pulse-code modulation.

All useful systems of this sort have this property in common: the signal-to-noise ratio out of the system differs from that into the system, and with proper choice of parameters can be made greater. Figure 4 shows a typical set of curves, which may be found in several of the references[1,2,3].

The datum system, single-sideband amplitude modulation, has no "improvement" property and so is represented by a straight line at 45 deg. For a given ratio of modulated-signal bandwidth to final output bandwidth, the signal-to-noise output of a "special system" at first rises faster, then levels out. If a higher bandwidth ratio is chosen, the signal/noise out flattens off at a higher level. It follows that if a given bandwidth ratio is available, the improvement defined as S/N out (db) minus S/N in (db) has a definite optimum which increases with this bandwidth ratio.

In Figure 5 this improvement is shown graphically for a number of systems. The quantitative figures marked on this graph should be taken in a rather broad sense: it is not possible to harmonize the practical results of all the theorists in this field because of the difficulty of getting agreeing standards of comparison. But the trend of the graphs is unmistakable. With systems of FM, PPM and PWM one can trade bandwidth for improvement in a fairly well-defined market. PCM has a law to itself, and represents the most profitable trading. (Delta-modulation, though irrelevant to the present discussion, is an interesting intermediate case.)

Now back to reading machines, which require a very high signal-to-noise ratio out. To be commercially useful, the machine should not make a mistake more often than, say, one in 10^7 figures. A high bandwidth ratio is available: if the limit is set by phosphor decay time with a reasonable safety margin, the input to the photomultiplier can be 10^6 bits per second, where only 10^3 bits per second are needed at the output (for reading sixteen characters at 250 per second.

In the clean-up process, the pulse-width standard uses an observed property of the signal by which long pulses have a higher information content than short pulses. This is trading bandwidth for signal-to-noise ratio in the profitable but inferior market characteristic of PWM. In the recognition process, however, the ERA uses properties of the signal taken in coded groups, thus trading in the superior market characteristic of PCM. The method of "combinations" is taken right to the end of the line. Since an actual mistake in recognition has worse consequences than a signaled "throw-out", the latter rather than the former is given whenever two or more output lines are excited at once.

Directions for future investigation

To begin with, the "noise" in a character must be defined. Such definition must begin with a statistical study of characters, and useful steps in this direction have been taken[4].

Secondly, it is desirable to put less weight on the clean-up and more on the logic, though there is an economic limit here: the logic costs much more than the pulse discrimination for a given percentage increase.

Thirdly, the bandwidth is not fully exploited because some areas of the figure contain much more information than others. Theoretically, it would be desirable to "shape" the scan so as to

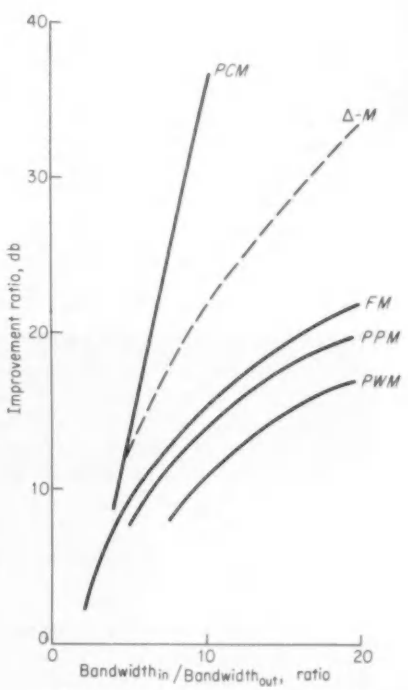

FIG. 5. Approximate "improvement" in signal-to-noise in output of specific systems vs. ratio of input to output bandwidths.

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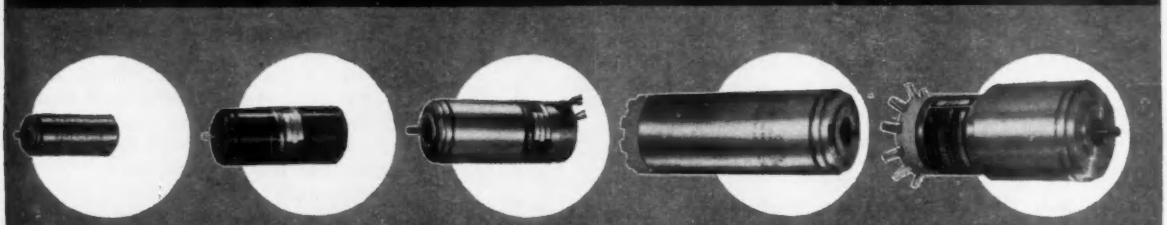

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*10MTG-6228-02	10	2.157	4.2	0.72	115	115/57.5	9,500	2.8	0.26	115	0.45	1.5	19	±10°
10MTG-6229-12	10	2.100	2.9	1.09	33/16.5	52/26	9,500	3.0	0.28	26	0.45	1.5	13	±10°
*10MTG-6229-03	10	2.100	2.9	1.09	26	26	10,500	3.0	0.26	18	0.3	1.5	12	±10°
10MTG-6229-15	10	2.100	2.9	1.09	26	26	10,500	3.0	0.26	26	0.3	1.5	12	±10°
*10MTG-6232-05	10	2.104	4.2	1.1	115	36/18	6,500	3.5	0.26	115	0.30	1.5	15	±10°
11MTG-6251-13	11	2.531	7.0	1.3	115	115/57.5	6,500	3.5	0.63	115	0.55	0.5	19	±10°
11MTG-6251-00	11	2.531	7.0	1.1	115	40/20	6,500	3.5	0.63	115	0.55	1.5	19	±10°
11MTG-6254-01	11	2.200	6.0	1.1	115	115/57.5	6,500	3.5	0.63	115	0.55	1.5	19	±10°
15MTG-6280-01	15	3.281	14.0	5.3	115	115/57.5	5,000	6.2	1.5	115	3.0	0.2	13	± 5°
†*15MTG-6276-03	15	3.875	15.0	4.4	115	57.5	8,500	5.8	0.70	115	2.75	0.2	13	± 0.5°
18MTG-6302-02	18	3.680	20.0	5.7	115	115/57.5	9,000	16.0	2.7	115	3.0	0.2	13	± 5°
18MTG-6302-04	18	3.680	20.0	5.7	115	115/57.5	4,800	9.2	2.4	115	3.0	0.2	13	± 5°

*These units designed for 85°C ambient but same characteristics can be designed for 125°C. †Additional 21.4 watts for heater, the values given are independent of ambient temperature.

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pack the features tightly in some parts, spread them in others. This is not done for the reason, always open to engineering attack, that it would be extremely inconvenient.

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Pneumatic Control for Differential Temperature

J. J. COMBES
Scientific Design Co.

In the system illustrated it was necessary not only to control the outlet temperature of the process reactor, but also to maintain an essentially constant temperature throughout the reactor; i.e., no hotspots. Some of the process details, as well as details of flow, level, and pressure controls, have been omitted since they are irrelevant to the control of reactor temperature.

The reactants are intimately mixed in the reactor and react upon contact with the evolution of heat. The temperature of the materials leaving the reactor is controlled by a miniature pneumatic recorder-controller which regulates the total flow of coolant to the reactor's two cooling coils, one for the upper half and the other for the lower half of the reactor.

To hold the reactor temperature uniform from top to bottom, these coils were connected in parallel and a three-way valve distributed the coolant between them in the correct proportions to absorb the varying amount of heat generated in the top and bottom sections. A differential temperature controller was needed to control the three-way valve. Conventionally, this would have called for an electric potentiometric type; but since in the reactor's temperature range (200 to 400 deg F) the shortest full-scale range recommended was a 20-deg differential, and the job had already been committed to pneumatic instruments with miniature controllers on the board, it was evident that pneumatic instruments would have to be used in some unusual way to measure the differential temperature.

Two pneumatic temperature transmitters *TM*-2 and *TM*-3, within the range 200 to 400 deg F, were decided upon. This meant that each degree of temperature change was equal to:

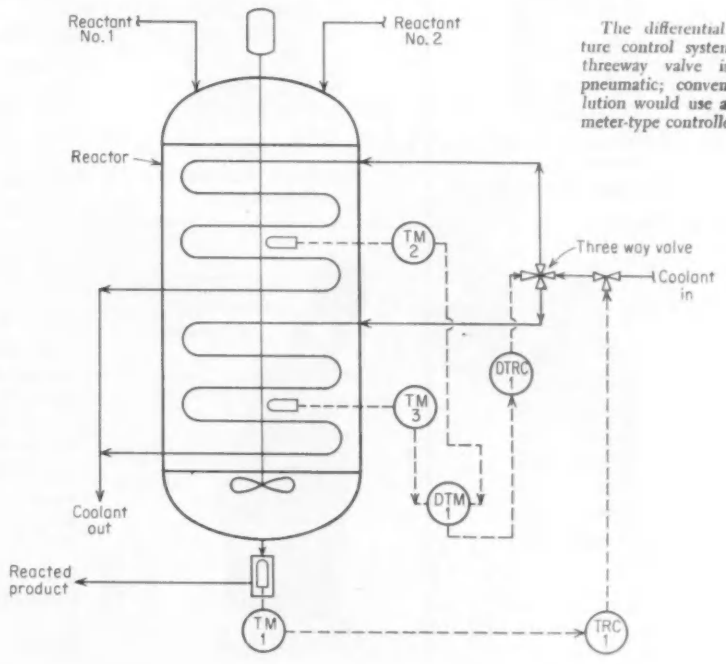
$$\frac{(15-3)}{400\text{-}200} \times 2.31 \times 12 = 1.662 \text{ in. of water change in transmitter output pressure}$$

where:

- 15 − 3 = output pressure range of 200 to 400 deg temperature transmitter
- 2.31 = ft of water per lb pressure
- 12 = in. per ft
- 400–200 = measuring range of temperature transmitter

A differential temperature transmitter range of plus or minus 5 deg (10 deg of temperature differential) was desired. To convert the temperature differential into a pneumatic signal that could be accepted by a pneumatic receiver-controller, conventional instruments were used in an unusual way. The output signal of one temperature transmitter was connected to the high pressure tap and the output signal of the other temperature transmitter to the low pressure tap of a 0-20 in. of water differential pressure transmitter. This transmitter was designated as a differential temperature transmitter *DTM*-1 and calibrated for a differential pressure range of 10 x 1.662 or 16.62 in. of water with an output of 9 psi at 0 in. differential, 3 psi at minus 8.31 in. differential, and 15 psi at plus 8.31 in. differential. It then transmitted to a pneumatic receiver controller *DTRC*-1 with its control point set at mid-scale (0 deg F differential temperature).

Although the connections are unconventional, the system works well, controlling differential temperature better than 0.025 deg F.



The differential temperature control system for the threeway valve is entirely pneumatic; conventional solution would use a potentiometer-type controller.

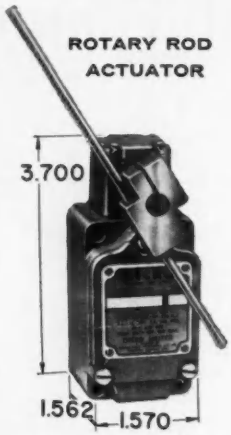
MICRO SWITCH Precision

...FIRST IN PRECISION SWITCHING

Two sound ways to

Compact "LS" Limit Switches are Available in 6 Different Actuator Designs

COIL-SPRING ACTUATOR



ROTARY ROD ACTUATOR

ROTARY ARM ACTUATOR

ROLLER PLUNGER ACTUATOR

PLUNGER (IN-LINE) ACTUATOR

ADJUSTABLE ROTARY ACTUATOR

These are small two-circuit, completely sealed limit switches. Their small size and versatility of mounting permits compact installation on all types of industrial machinery which require dependable long-life precision switch gear.

In this "LS" series there are six actuator designs. All rotary actuators are field adjustable to operate in clockwise direction, counter-clockwise, and in both directions—with operation point adjustable to any position thru 360 degrees. Their heads can be faced in any of four positions.

The ½"-N.P.T. internally tapped conduit opening is in the bottom of the housing. The replaceable basic switching unit within enclosure has No. 8 terminal screws.

COIL-SPRING ACTUATOR

Can be operated from any direction. Useful in foundry, conveyor and packaging operations.

ROTARY ROD ACTUATOR

Has extremely low force characteristics. Rod is adjustable to any length. Operating point and direction are adjustable. Excellent for use in counting and detecting applications.

ROTARY ARM ACTUATOR

The heavy duty forged aluminum arm actuator with roller is designed for cam and slide operation. Field adjustable operating point and direction. Its uses are unlimited.

ROLLER PLUNGER ACTUATOR

For slow-rise cams or slides, this actuator head can be rotated 90° for operation by cams whose approach is perpendicular to the mounting surface of the switch.

PLUNGER (IN-LINE) ACTUATOR

For use where the switch can be located so that the switch plunger motion is in line with the actuating device. Plunger has ¼ inch overtravel.

ADJUSTABLE ROTARY ACTUATOR

Roller lever arm length is adjustable to any point in a 2½ inch range. Head assembly can be positioned to any of 4 sides of switch. Actuating direction and operating point are adjustable.

For details as to electrical ratings, mechanical characteristics, adjustability, and other features on this series of limit switches, ask for Data Sheet 138 and Catalog 83 on enclosed switches.

Switches have uses unlimited

improve initial design

The New "E6" and "V6"... Easier Installation ... Better Sealing ... Improved Insulation

The new "E6" and "V6" series of small limit switches have many new and improved features over the design first introduced by MICRO SWITCH in 1939. This design is the smallest and most compact enclosed limit switch available for all industrial uses. This new series is interchangeable with the old series—same mounting holes, and same envelope (housing) dimensions.

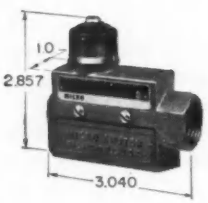
The new housing is divided into two parts with the terminal screws exposed. This saves wiring time.

The new one-piece elastomer combination insulator and seal is cemented into the bottom half of the switch assembly, replacing a separate gasket and wrap-around glass cloth insulator. This saves installation time and provides excellent insulation and sealing of the enclosure when assembled.

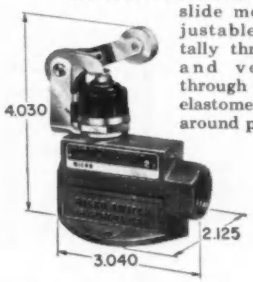
The new housings have heavier walls yet envelope (housing) dimensions are the same as the old design. Hexagonal conduit hub facilitates connecting of conduit.

Six different actuator types are available. All six are available in either side mounting (E6) or bottom mounting (V6) designs.

Ask for Data Sheet 145 and Catalog 83 for data on line of enclosed switches.

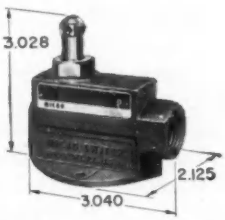


Actuator for straight, in-line operating motion with controlled overtravel. Elastomer seal boot around actuator protects against dirt and moisture.

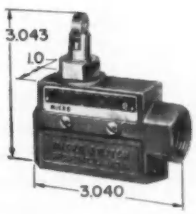


Roller lever actuator for cam or slide motion, adjustable horizontally through 360° and vertically through 225°. Has elastomer seal boot around plunger.

Plunger actuator for straight, in-line operating motion with controlled overtravel.



Roller plunger actuator for slow-rise cam or slide motion with controlled overtravel. Roller in line with case.



Roller plunger actuator for cam or slide motion with controlled overtravel. Roller at 90° angle to case.

Roller lever actuator for cam or slide motion, adjustable horizontally through 360° and vertically through 225°.

MICRO SWITCH . . . Freeport, Illinois
A Division of Honeywell

The two-word name MICRO SWITCH is NOT a generic term. It is the name of a division of Honeywell.

Honeywell

MICRO SWITCH PRECISION SWITCHES

The Year Advertising Helped

This editorial message was first published by McGraw-Hill two years ago. It describes advertising's dramatic contribution to the American economy during 1954. The theme of the editorial—that advertising can help promote economic stability by stimulating sales at a crucial time—is even more pertinent today.

As our economy grows, it is constantly changing. The conditions business faces today are not the same in every respect as those it faced in 1954. But business again has the opportunity, through advertising and other selling efforts, to help sustain a high level of economic activity. At the same time, it will be building markets for the period of renewed expansion that is sure to follow.

This editorial is reprinted exactly as it appeared in 1956 except for minor editorial changes to bring it up to date. Permission is freely extended to newspapers, groups or individuals to quote or reprint all or parts of the text.

Donald C. McGraw

PRESIDENT

McGraw-Hill Publishing Company, Inc.

IN 1954 we had a business recession in the United States. Sales fell about 4% during the year. If management had followed the historic pattern of business ups and downs, advertising volume would have fallen much further.

But in 1954 the volume of advertising did not fall. It increased over 5%, and expenditures in all major advertising media rose. Every effort was made to stimulate sales when sales were needed to sustain prosperity.

This was something entirely new under the sun. It had a powerful influence in making the recession of 1953-54 one of the mildest on record. It helped greatly to speed business on to the record-breaking levels it attained in the years 1955-57.

There are several reasons why America's business management attacked this decline in sales with more advertising. One of them grew out of the greatly strengthened position of the American consuming market. Consumers' income after taxes has been rising an average of over $10 billion a year since 1946, and this rising income is more widely distributed than ever before. Furthermore, consumers had piled up reserves of about $200 billion in cash or its equivalent. These reserves offered a new and powerful inducement to increased selling and advertising effort even in the face of a possible decline in consumer income. (At the end of 1957, consumer reserves were $225 billion.)

Taking the Longer View

However, the principal reason why a sales decline was attacked with increased advertising is management's new-found conviction that good advertising is essentially an investment in the development of a market. Successful development requires sustained investment. The inclination of business management to take this longer view is, of course, motivated

McGraw-Hill PUBLISHING COMPANY,

ABP HEADQUARTERS FOR

Kill a Business Recession

by the fact that the American market, with over 3 million consumers being added annually, is growing at a prodigious rate.

Ten years ago only a handful of companies had plans for investment in new producing facilities extending beyond the current year. Today almost all leading companies have investment programs running some years ahead. And keeping pace with these long-range investment plans has been the development of sales and advertising programs to reach tomorrow's greatly expanded markets.

Advertising's Key Role

This crucial role of advertising in providing driving power for our economy is gaining greater recognition every day. In his book, "People of Plenty," Professor David M. Potter of Yale University remarked: "Advertising is not badly needed in an economy of scarcity, because total demand is usually equal to or in excess of total supply, and every producer can normally sell as much as he produces. It is when potential supply outstrips demand—that is, when abundance prevails—that advertising begins to fulfill a really essential economic function."

Today abundance so completely prevails in the United States that it has been conservatively estimated that as much as a third of everything offered for sale falls in the realm of "optional consumption." That is, consumers can "take it or leave it" without any immediate personal inconvenience. But if they decide to "leave it," a terrific economic depression will not be far behind. In such circumstances, advertising—in which, in all of its forms, we are now investing over $10 billion annually—clearly is of crucial importance to our continued prosperity.

In performing its key role in past years, American advertising never realized its full potential. It successfully promoted sales. But it never was called upon to promote an overall economic stability as a direct outgrowth of increased sales.

By successfully promoting both sales and economic stability, as it did in 1954, advertising surely has added new strength to the American economy. It has also added a great new and constructive dimension to advertising itself.

One of the surest means of expanding your sales volume in today's industrial markets is through dominant advertising in the publications directly serving your major customers and prospects.

McGraw-Hill's business and technical publications can give you quick access to the men who initiate, specify and approve the purchases of industrial products and services. Because all are leaders in their respective fields, you are assured a maximum return on your advertising investment when you *concentrate* in the McGraw-Hill publications serving your most important markets.

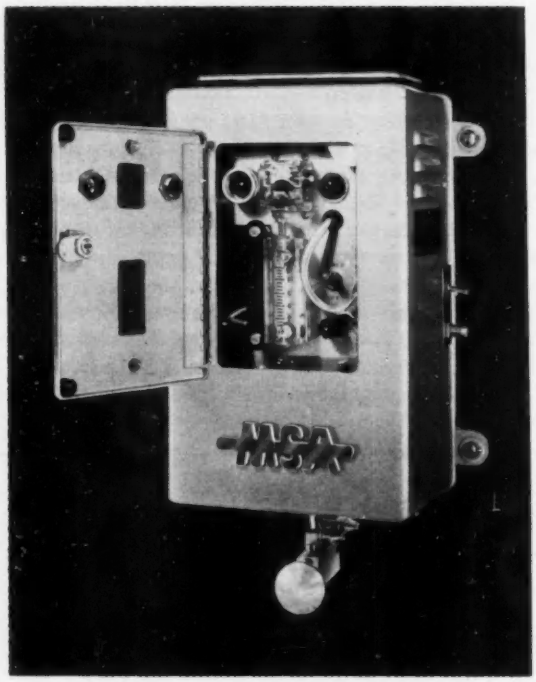
INCORPORATED · 330 West 42nd St., New York 36, N. Y.

BUSINESS INFORMATION

NEW PRODUCTS

LISTING IN GROUPS

Designs of the Month
Data Handling & Display
Primary Elements & Transducers
Controllers, Switches & Relays
Actuators & Final Control Elements
Research, Test & Development
Component Parts
Accessories & Materials

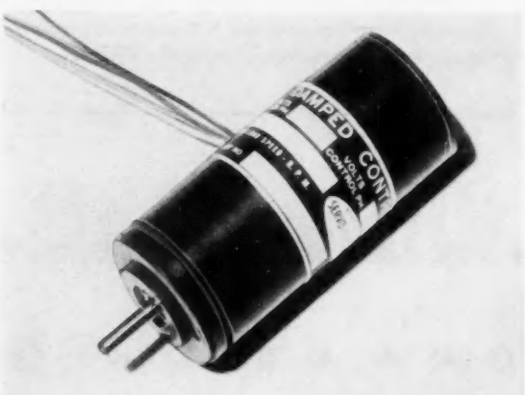


COMPACT GAS ALARM checks atmosphere.

This new self-contained combustible-gas alarm, which operates on the same principle as the maker's larger units, mounts in a cabinet measuring 8¾ by 6¼ by 14½ in. high and features a minimum first cost and low maintenance. Called the Explosilarm, it is well-suited for industrial plants handling combustible gas. An integral vacuum pump draws a sample stream across a heated filament that is one resistance arm of a Wheatstone bridge circuit. Any combustile gas present burns catalytically at the hot filament surface, raising its temperature—and its resistance. Unbalance of the bridge circuit causes an output voltage proportional to the concentration of combustible gases. At some preset value, this signal actuates an alarm light or horn.

Platinum filaments in the balanced-bridge circuit are specially designed for long life, interchangeability without matching pairs, and extreme zero and calibration stability. A locking front panel prevents tampering with controls by unauthorized personnel. Motor and pump assembly, meter, relay, and all other components are housed within the cabinet. The instrument is designed for installation in nonhazardous areas. To convey the sample stream out of the potentially-explosive area to the instrument, a sample line as long as 50 ft may be used. Sample-volume flow rate through this line is 4½ liters per min.—Mine Safety Appliance Co., Pittsburgh, Pa.

Circle No. 1 on reply card



SIZE 11 MOTOR has inertial damper.

The 11P1-3 inertially damped servomotor operates directly from a 115-volt line, and has a 40-volt center-tapped control phase winding. Special control phase windings up to 180 volts, center-tapped for transistor and magnetic amplifier drives, are available on request. Characteristics include a minimum no-load speed of 6,200 rpm and a minimum stall torque of 0.6 oz-in. The integral inertial damper operates under acceleration and deceleration by magnetically coupling a low-inertia drag cup to a freely-rotating, permanent-magnet flywheel. At constant velocity, there is no reduction in speed or output power. Built-in precision gearheads offer speed ratios up to 16,000:1.—Mechatrol Div. of Servomechanisms, Inc., Westbury, N. Y.

Circle No. 2 on reply card

NEW MOTOR needs no converter.

The Model 7105 Digistepper, a unique digital actuator motor, requires no digital-to-analog conversion; it operates directly on digital pulses. Digital control of gyros and magnetic recording heads, positioning of machine tools, and other areas where overshoot is intolerable are among the applications. The unit will accommodate digital stepping rates as high as 60 per sec in either direction. Normal angular travel of 180 deg per step can be swapped for increased torque. Typical motor with a 180:1 gear head produces 80 oz-in. of torque for a 1-deg step. Relay box in photo measures 2 by 3 by 4 in. long.–The Digitran Co., Pasadena, Calif.

Circle No. 3 on reply card

AIRSPEED COMPUTER suits subsonic use.

The AXC-529 computer, which provides a shaft output proportional to true airspeed, will be used chiefly in airborne navigational systems. Designed for subsonic use, the new computer features an accuracy within 2 knots over a range of from 100 to 250 knots (about 115-286 mph). In operation, the device uses two transducers–a force balance Mach meter and a total temperature probe–to determine Mach number from static and total pressure signals, and to provide temperature compensation. Transistorized amplifiers keep the weight below 12 lb. Power requirements are 125 watts (25 watts at 400 cps for computing and 100 watts, ac or dc, for heating).–Servomechanisms, Inc., Hawthorne, Calif.

Circle No. 4 on reply card

PHASE SHIFTER cuts testing time.

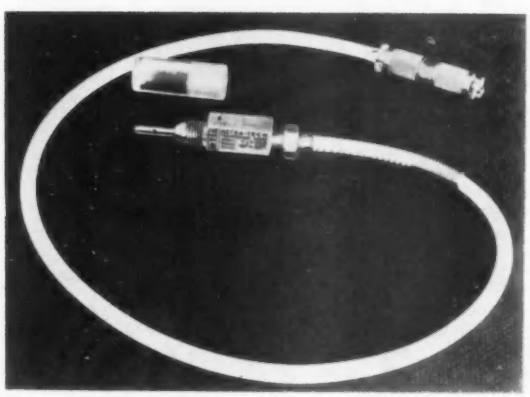
Called the Faze Box, this handy phase-shifting device is versatile, simple, and low in cost. It accepts signals as high as 30 volts rms through its transformer-isolated input, and produces 0 to plus or minus 180 deg shifts over a frequency range from 25 to 10,000 cps Controls include a 180-deg fixed-phase-shift selector switch, an 11-position step switch, and a continuously-variable fine control. In a typical application, the box is inserted between the output of a differential-transformer type pickoff and the input to a demodulator, or between the output of a synchro and the input of a servoamplifier, to compensate for phase shift in the pickoff device.–American Measurement & Control, Inc., Waltham, Mass.

Circle No. 5 on reply card

TEMPERATURE PICKUP responds fast.

Designed for measuring static and flow temperatures in liquid gases, this new transducer responds within 10 millisec (1 millisec with the maker's own amplifier). Accuracy and resolution are within 0.1 deg F. With the matching amplifier, the device provides an output of plus or minus 5 vdc per 100 deg F. Other specs include a maximum operating current of 5 ma and eight operating ranges (minus 450 deg F to plus 2,000 deg F). The rugged probes will withstand accelerations as high as plus or minus 25 g's at frequencies of 0 to 200 cps.–Astra Technical Instrument Corp., South Pasadena, Calif.

Circle No. 6 on reply card



DATA HANDLING & DISPLAY

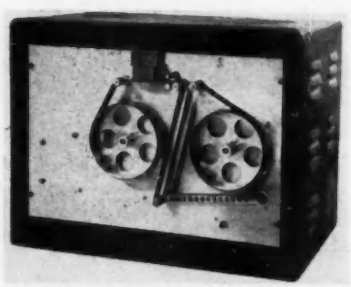
PRESSURE LOGGER

With this automatic digital data logger 24 or 48 pressure lines can be fed into a single transducer. Output can be punched on a tape or typewritten.

Characteristics:

Scanning rate: 4 points per sec
Accuracy: within ¼ percent, including transducer
Repeatability: within $\frac{1}{10}$ percent
Range: 0 to 350 psi, absolute, gage, or differential
—Hanson-Gorill-Bryan, Inc., Glen Cove, Long Island, N. Y.

Circle No. 7 on reply card



10 MILLION BITS

The model 3270 Miniature Random Access Memory stores up to 10 million bits with an average access time of less than ½ sec. The unit is designed to store large amounts of digital data for use by computers and other data-processing devices; it consists of two reels containing approximately 35 ft of tape which can be swept past the reading head in either direction in less than half a second. Capacity can be increased by adding more units.—Potter Instrument Co., Plainview, N. Y.

Circle No. 8 on reply card

ELECTRONIC INTEGRATOR

A new electronic integrator measures relative quantities of gas-mixture components with 1 percent accuracy. It's adaptable to industrial processes where the measured variable must be integrated.

Characteristics:

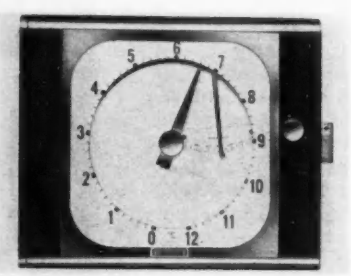
Counting rate: 2,400, 1,200, or 600 counts per minute
Accuracy: plus or minus 1 percent
Power required: 115-volts, 60 cycles, 150 VA regulated
Optional readout: High-speed five-digit electromechanical
—Barber-Colman Co., Rockford, Ill.

Circle No. 9 on reply card

BINARY TIMER

The binary timer shown here codifies the time base in sampling or telemetering systems to simplify data reduction. Binary counts are available at one per second continuously; each second a synchronizing commutator pulse is followed by an identifying eight-bit binary encoded pulse train. Unit is hermetically sealed and air-worthy.—Instrument Development Labratories, Inc., Attleboro, Mass.

Circle No. 10 on reply card



HUGE FACE

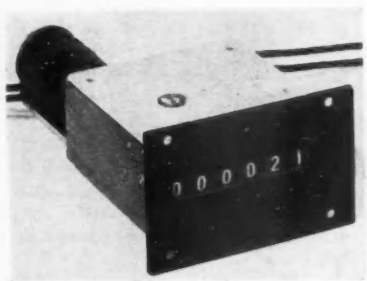
Large face in photo is the 32-in. scale of a self-balancing electronic potentiometer designed to be read from a distance. Unit can be used to measure variables such as temperature, speed, pH, and pressure.—Bristol Co., Waterbury, Conn.

Circle No. 11 on reply card

ULTRASONIC GAGE

The ultrasonic thickness gage in the photo measures metals, glass, and plastic between 0.005 and 2.5 in. It can be used for thickness gaging, detection of laminar flaws, and sorting. Gating and alarm circuits trip relays when a part is too thick, and in sufficient quantities, control thickness sorting.—Branson Instruments, Inc., Stamford, Conn.

Circle No. 12 on reply card



QUICK-RESET COUNTERS

Compact, panel-mounted, high-speed electrical counters, designed to fill the gap between standard and electronic counters, are now available for industrial, data processing, and scientific applications. Features include long life, instant reset, and large figures in the readout. Rated speed is 3,000 counts per min, but units have been tested at 6,000 counts per min for extended periods. Actual counter life is expected to exceed 200 million counts. A newly designed heart-cam mechanism provides the instant reset.—Veeder-Root Inc., Hartford, Conn.

Circle No. 13 on reply card

Count, Read, Print

with CMC's COMPLETE NEW PACKAGE

✓ **UNIVERSAL COUNTER & TIMER**

0 cps to 1 mc

3 microseconds to 1,000,000 seconds

✓ **READABLE READOUT**

Inline-Inplane, up to 12 presentations per second

✓ **FAST PRINTER**

Permanent printed record at 4 lines per second

CMC's complete counting, timing, and frequency measuring system for laboratory and industrial use.

KEY SPECIFICATIONS

	Model 226A Universal Counter & Timer	
Ranges		
Frequency	0 cps to 1 mc	
Time Interval	3 μsec to 10^6 sec	
Period	10 μsec to 10^6 sec	
Accuracy	±1 count ± crystal stability	
Crystal Stability	±3 parts in 10^6 per week	
Sensitivity (all functions)	0.2 v rms	
Oscilloscope Trigger Level Marker Signals	Start and stop channel trigger level adjustment for time interval measurement of complex wave forms; trigger level adjustment for amplitude discrimination in frequency and period measurement.	
Decimal Point Indication	Automatic	
Price (f.o.b. factory)	$1100.00	
	Model 400B Digital Printer	**Model 401A In-Line Readout**
Capacity	6 digits – Up to 12 digits optional	6 digits
Max. Cycling Rate	4 lines per second	12 presentations per sec.
Digit Size		1⅜" W x 2¼" H
Accuracy	Identical to counting instrument	
Input Requirements	4 line 1-2-2-4 code from counting instrument (adaptable to 1-2-4-8)	
Price (f.o.b. factory)	$850.00	$770.00

Now, at the lowest cost in the industry, you can get high quality advanced counting, timing, and frequency measuring instrumentation from CMC.

Using CMC's new *readable* readout and fast printer working in combination with the Model 226A 1 mc Universal Counter and Timer, you can measure, read, and record frequency, frequency ratio, period and time interval. Thru the use of standard transducers, basic physical quantities such as pressure, velocity, acceleration, displacement, flow, rps, and rpm can be measured, read, and permanently recorded. The Model 226A is also a convenient secondary frequency standard providing a time base for other instrumentation. All instruments feature unitized construction for structural strength and reduced weight.

☞ *Compare these key specifications before you choose.*

For a demonstration, contact your nearest CMC engineering representative. For complete technical information, please write Dept. **085**.

Subsidiary of Hancock Manufacturing Company

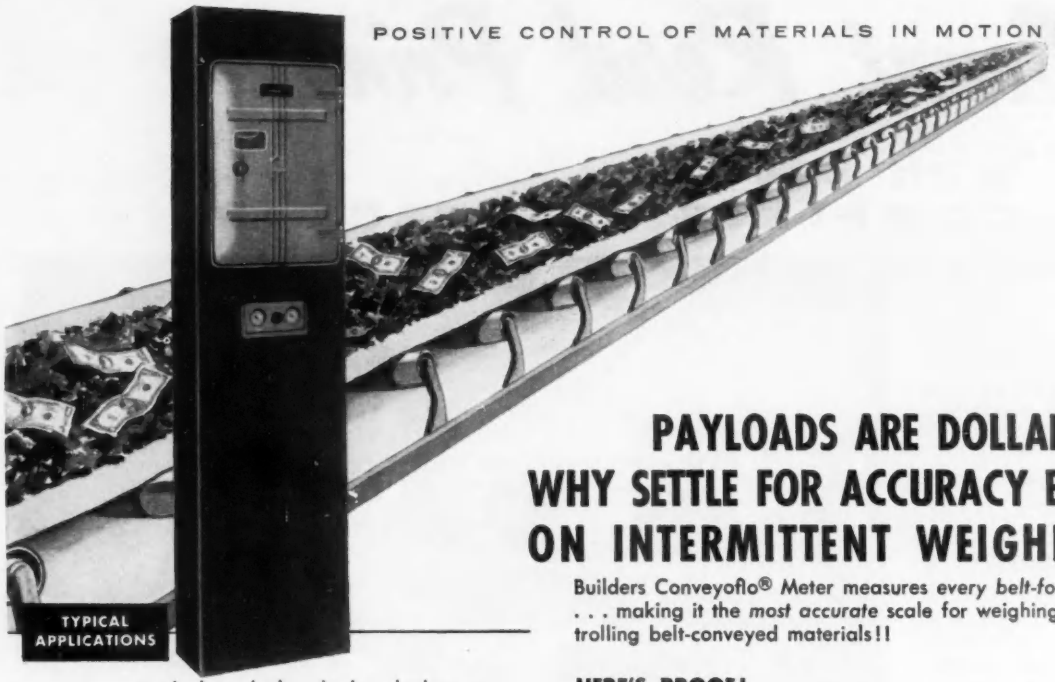
CMC

Computer-Measurements Corporation

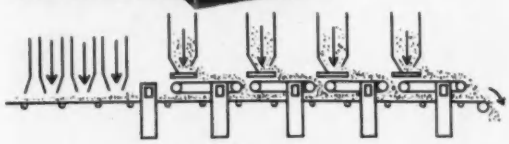
5528 Vineland Ave. • No. Hollywood, Calif.

Phone: STanley 7-0401 • TWX: N HOL 2160

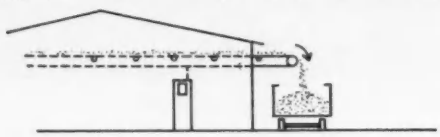
POSITIVE CONTROL OF MATERIALS IN MOTION B-I-F



TYPICAL APPLICATIONS



Sinter Process Control



Freight Car Loading

PAYLOADS ARE DOLLARS... WHY SETTLE FOR ACCURACY BASED ON INTERMITTENT WEIGHING?

Builders Conveyoflo® Meter measures *every belt-foot of load* . . . making it the *most accurate* scale for weighing and controlling belt-conveyed materials!!

HERE'S PROOF!

CASE NO. 1: Conveyoflo Meters automatically control the sintering process in a major steel plant.* One phase of operation calls for *one* scale to weigh the ore while *four* other scales automatically control additives. The combined loads from all *five* scales eventually pass over a *sixth* scale. A recent check for a 24-hour run produced the following results:

Total Tonnage from 5 scales.....4050.7
Total Tonnage registered by 6th scale...4053.5
Difference (tons).....2.8 or **0.069% . . . ACCURACY!!**

CASE NO. 2: Conveyoflo Meters are used by one of the country's largest producers of power* to inventory incoming coal. On one 17-day run, the totals of two Conveyoflo Meters were compared with the bills of lading with the following results:

Bills of Lading .....74,880.4 Tons
Conveyoflo Meter Totals ....74,848.0 Tons
Difference —32.4 Tons or **—0.0432% . . . ACCURACY over a 17-day period.**

*Names and locations upon request!

Builders-Providence Conveyoflo is designed to fit any standard conveyor. Start saving dollars today. Write for Bulletin 550-P5, **Builders-Providence, Inc., 528 Harris Ave., Providence 1, Rhode Island.**

FEATURES:

- **ACCURACY** . . . within ±0.5 of 1% of full scale load over a 10:1 range.
- **UNLIMITED CAPACITY** . . . each scale individually sized to the specific requirements of the installation.
- **UNAFFECTED BY OVERLOADING** . . . overloading will not damage the live force-balance weigh cell, or cause any shift in calibration of this scale.
- **PNEUMATIC FORCE-BALANCE WEIGH CELL** . . . generates powerful (5 to 15 psi) signals requiring no amplification . . . sensitive, but rugged, simple, and reliable!
- **CONTINUOUS INTEGRATOR** . . . adds and subtracts to provide true zero with empty belt . . . contributes to the exceptional accuracy of Conveyoflo Meters!

NEW LITERATURE

Please send me the POSITIVE FLOW CONTROL bulletins checked below:

- ☐ Shuntflo Bulletin (400-J10A) . . . for metering air, gas, steam
- ☐ Propeloflo Bulletin (380-K4B) . . . for metering water
- ☐ Conveyoflo Bulletin (550-P5) . . . for weighing belt-conveyed materials
- ☐ Chronoflo Bulletin (230-H4B) . . . for telemetering and control
- ☐ Venturi Flow Nozzle Bulletin 130-E2A . . . for high pressure, high temperature metering
- ☐ Dall Flow Tube (DFT-P1) Bulletin (125-P3) . . . for low cost, specialized metering

Name.....
Company.....
Address.....
City.....*State*.....

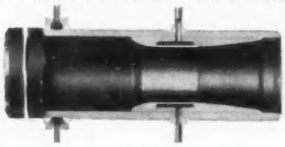
BUILDERS-PROVIDENCE
DIVISION OF
B-I-F INDUSTRIES B-I-F METERS FEEDERS CONTROLS

SPECIFY BIF

FLOW METERING ELEMENTS FOR CORROSIVE FLUIDS

Builders Model DFT-PI Dall Flow Tube . . . insert-type, plastic primary metering element. Low cost, accurate. Suitable for most applications, especially corrosive fluids. Bulletin 115-R1.

FOR HIGH PRESSURES & TEMPERATURES

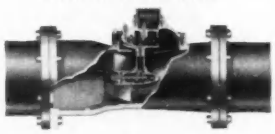


Builders X-TRA-HI Flow Meters . . . for high temperature, high pressure applications . . . proven in primary loop of every major atomic reactor in America. Bulletin 130-E2A.

REMOTE METERING/CONTROL

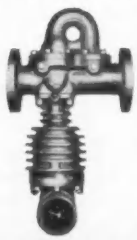
Builders CHRONO-FLO® Telemeter . . . sends data on remote flows, pressures, temperatures, tank levels, etc. Remotely controls pumps, valves. Bulletin 230-H4B.

LIQUID METERING



Builders PROPELOFLO® Meter . . . direct-reading, propeller-type liquid meter . . . 2″ to 20″ lines . . . within ±2% of actual flow over specified range . . . capacities ranging from 15 to 5,800 GPM. Bulletin 380-K4B.

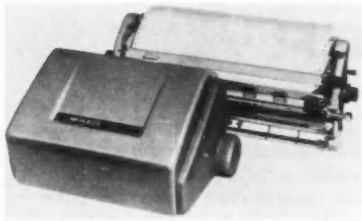
STEAM, AIR, GAS METERING



Builders Shuntflo Meter . . . self-contained, self-operated meter . . . for 1″ to 24″ line sizes . . . accurate within ±2% of actual rate of flow. Provides continuous and automatic pressure compensation. Bulletin 400-J10A.

MAIL COUPON TODAY!

NEW PRODUCTS

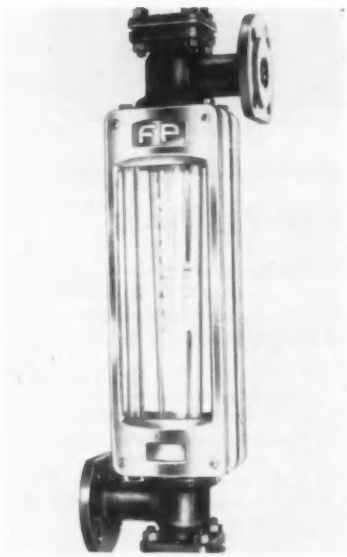


DATA-LOGGER

No pulse or control circuits are necessary here because this automatic data logger has its own. It also has its own power supply, and is capable of handling an entry of 14 digits simultaneously. The MC-203 machines are capable of 150 printings per minute.–Monroe Calculating Machine Co., San Francisco, Calif.

Circle No. 14 on reply card

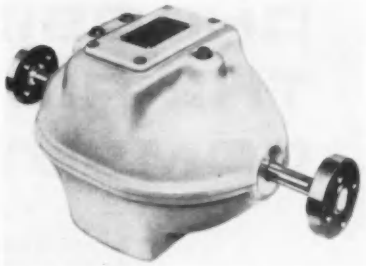
PRIMARY ELEMENTS & TRANSDUCERS



CORROSION-PROOF

This rugged, variable-area flowmeter uses vitreous-enamel-lined fittings that enable it to handle a wide range of corrosive fluids. Unlike rubber-lined, porcelain, hard lead, and special alloy meters, this new instrument will withstand high temperature and shocks.–Fischer & Porter Co., Hatboro, Pa.

Circle No. 15 on reply card



FOR SMALLER LINES

The magnetic flow meter shown is now available for ½-in. flow lines. Previously the meter was limited to 1-in. or larger lines. Meter performance is unaffected by pressure, viscosity, density or conductivity changes in the flowing liquid. Overall accuracy is 1 percent.–The Foxboro Co., Foxboro, Mass.

Circle No. 16 on reply card

CHLORINE ANALYZER

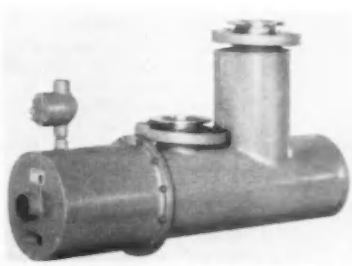
A new chlorine analyzer which measures free, combined, or residual chlorine is essentially a double light beam photometer. Analyzer is supplied in two standard ranges: zero to one and zero to ten parts per million. Accuracy is within one percent.–Fischer & Porter Co., Hatboro, Pa.

Circle No. 17 on reply card

MINIATURE TRANSDUCERS

A new line of miniature pressure transducers incorporates infinite-resolution potentiometers. Transducers are available in ranges from 15 to 300 psi gage, absolute, or differential. Transducer can stand vibrational loadings of 15 g's between 2 and 20 kc, and their resistor life is roughly 25 to 50 million cycles.–Rahm Instruments, Westbury, Long Island, N. Y.

Circle No. 18 on reply card



MEASURES FLUID DENSITY

The radioactivity gage shown measures fluid density, specific gravity, or percent solids in a liquid continuously and automatically. A radioactive

CHOOSING THE RIGHT COMPUTER

An analog computer can be your basic tool for design, analysis, and control. You can solve a host of equations and simulate a variety of physical and chemical processes. You can even put the computer to work controlling the whole loop. You can do all these things quickly, conveniently and economically if you choose the right computer.

The Donner 3100 with non-linear equipment

WHAT ARE THE CRITERIA?

Functional versatility and operational convenience. In a great measure, the new Donner 3100 combines these key characteristics at a better price than any other computer on the market. Here are some of the things that add up to functional versatility and operational convenience:

- ★ *Built-in simulation board in addition to regular patch board.*
- ★ *The functions of the amplifiers are uncommitted.*
- ★ *The Donner is designed for expansion. You can start with as few as ten amplifiers.*
- ★ *Electronic multipliers to accommodate non-linear terms.*
- ★ *Electronic transport delay generators to simulate "dead time."*
- ★ *24-point function generators for synthesis of arbitrary functions.*
- ★ *Diodes to create limiting, backlash, and dead zone effects.*
- ★ *A true operating console.*
- ★ *Two or more computers can be interconnected.*
- ★ *Accommodates extra amplifiers at the simulation board for other uses such as special transfer functions.*

Prices for this high accuracy, medium size analog computer begin at $12,775 for a computer with 10 chopper-stabilized amplifiers and 20 coefficient potentiometers. $16,650 purchases this computer with 30 amplifiers and 40 pots. We have prepared an eight page data file describing the new Donner 3100. Yours for the asking. Please address Dept. 085.

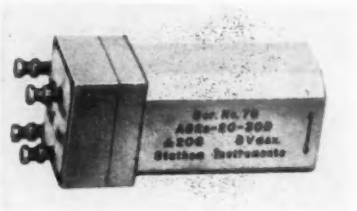
DONNER SCIENTIFIC COMPANY

CONCORD, CALIFORNIA

NEW PRODUCTS

source and detecting cell combination converts radioactive energy directly into electrical energy proportional to fluid density. Range can be as narrow as 0.05 specific gravity units with a precision of plus or minus 2 percent.–Ohmart Corp., Cincinnati, Ohio

Circle No. 19 on reply card



7.2 GRAMS

The longest dimension of this linear accelerometer is less than an inch, and its weight is only 7.2 grams. Output is 32 millivolts full scale, open circuit, per eight volts excitation. Close calibration and rugged design fit the accelerometer to aircraft or missile uses.–Statham Instruments, Inc., Los Angeles, Calif.

Circle No. 20 on reply card

FOR PROCESS CONTROL

The Model F Combustible Gas Analyzer centralizes process control samples intermittently, and measures combustible gases and vapors in air. Condensation of combustibles is eliminated by high-temperature filaments which heat the gas in their vicinity. Remote analyzing heads in explosion-proof housings enable the instrument to sample six stations continuously, or eight intermittently.

Characteristics:

Control units: either tube or remote-head sampling
Number of stations: 4, 6, or 8-point scanning; two monitors permit 16-point sampling
Sampling time: 30 sec
Response time: almost instantaneous with remote heads; with tube sampling, it is maximized by a flow rate exceeding 0.5 ft per sec through $\frac{3}{8}$ in. tubing
Warning and monitoring units: optional filament
Variation: 15 percent in sample flow does not affect filament–Mine Safety Appliances Co., Pittsburgh, Pa.

Circle No. 21 on reply card

advertisement

air circuitry:

a sales tool for you

—Air is booming as an industrial control medium. Air Circuitry* has recently been applied to jobs where it never would have been considered a few years ago! Westinghouse pneumatic engineers have designed and installed Air Circuitry systems for original equipment which have boosted production and cut time and labor expenses for a wide variety of industries including electronics, textiles, automobiles, chemicals, and aircraft.

The benefits of advanced air control are well known among plant engineers. But you can apply these advantages with the same happy results in *your design* of machinery used in manufacturing operations.

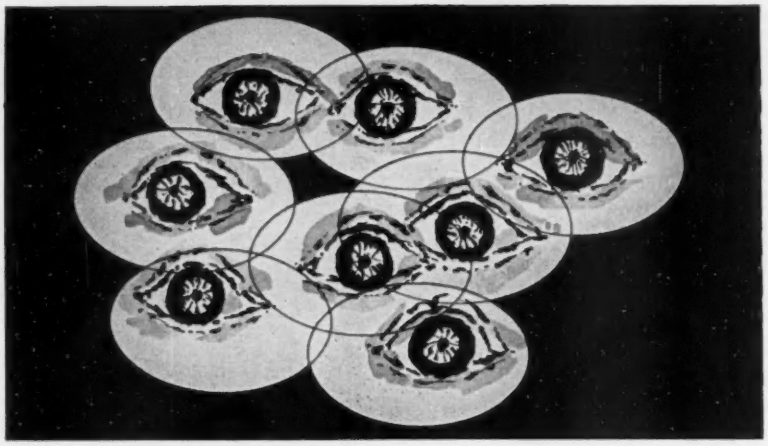
SELLING ADVANTAGES—No other medium offers such safety . . . such dependability. Above all, only air can offer such economy: the medium is free and available in limitless supply; the devices are not expensive; and repairs can be made easily by unskilled personnel. These are all-important factors—factors which *sell* factory and machine shop supervisors!

SEE FOR YOURSELF. We'll send a qualified control engineer to your plant. He will show you if and how pneumatic control can improve your present design, and he'll estimate the cost of conversion. If we can't give you simpler, more reliable controls, you don't owe us a cent; our service is free.

Let us study your control systems. Let us improve them, with air. Just write to Westinghouse Air Brake Company. Industrial Products Division, Dept. RS5, Wilmerding, Pennsylvania. Give us a description of your line of machinery, and the type of control it is now using. We'll do the rest.

Remember, Westinghouse has led the world in the design and manufacture of pneumatic devices for more than 90 years. We bring world-wide experience to the solution of your control problems. We bring world-wide service to those who use machines equipped with Westinghouse Air Circuitry.

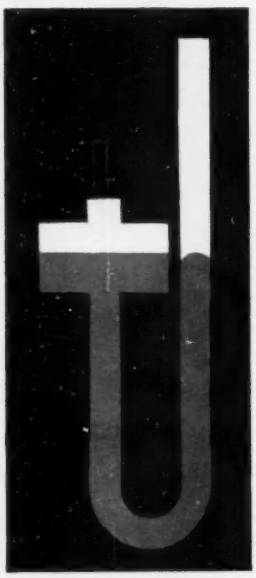
*AIR CIRCUITRY is the Westinghouse term for application of pneumatic control systems to industrial production operations.



• • • for blind transmitters

Raised-Well Type Manometers

Raised-well type manometers permit zero to be located at any specified point on the scale; with pressure readings upscale, vacuum readings downscale; or in terms absolute. More details in Bulletin G-14.



Eye-witness verification of your non-indicating transmitters is simply, economically obtained with Meriam Manometers.
Manometers will enable your operators to check calibrations at all times . . . to tune control set points more precisely . . . to visually "read out" and log selected values more accurately . . . to continue operation during transmission interruptions.
There are Meriam Manometers especially constructed for outdoor exposure; for working pressures up to 2000 psig. They can bring otherwise unattainable accuracy *and reproducibility* to your plant instrumentation. Only a manometer gives *perfect* reproducibility . . . and reads out to whatever sensitivity you require. And, manometer accuracy is for keeps . . . never requires recalibration. Centralized instrumentation, today, requires the back-up of manometers . . . out where the measurement begins.

NEW

. . . complete and informative guide to manometer theory and practice as well as manometer models for plant, field and laboratory use. Just ask for Bulletin G-14. The Meriam Instrument Company, 10920 Madison Avenue, Cleveland 2, Ohio.

FLOWS · PRESSURES · VACUUMS · LEVELS · DIFFERENTIALS

MERIAM MANOMETERS
...always accurate

CONTROLLERS, SWITCHES & RELAYS

ADJUSTABLE RATE SWITCH

This externally adjustable rate switch contains a gyro which trips a switch when some preset rate of turn is reached. The external adjustment allows aircraft and missile users to stock rate switches, set ranges as desired.

Characteristics:

Available ranges: 1-10, 5-50, and 10-500 deg per sec (others also)
Contact rating: 2.5 amp
Accuracy: within 10 deg per sec
Temperature range: minus 65 to plus 165 deg F
Vibration and shock: 40g's shock, plus or minus 10g's vibration to 500 cps.
Weight: approximately 1 lb
—Humphrey, Inc., San Diego, Calif.

Circle No. 22 on reply card

TWO AT A TIME

This repeat-cycle timer works on the reversible motor principle and can control two separate load circuits for on-off cycling over its entire range. It has no springs, solenoids or ratchets.—Automatic Timing & Controls, Inc., King of Prussia, Pa.

Circle No. 23 on reply card

Barden Precision SR1-4 miniature bearings as used in a linear or non-linear potentiometer.

BARDEN *miniature-size bearings are built with instrument precision*

The Talyrond, a super-accurate measuring device, is used by Barden as a development tool; as a standard for correlation of other quality control instrumentation; as a gage for ultra-precise bearing parts. It measures roundness and waviness to five millionths of an inch.

Precision-built potentiometers require concentric, smooth-running wiper contacts and ultra low torque characteristics to provide accurate and rapid response to small motivating forces.

Barden Precision miniature-size bearings have the inherent concentricity, smoothness and low torque values to assure this sensitive response and electrical accuracy.

Barden Precision miniature bearings are built to the same high standards of consistent quality as Barden's larger instrument sizes. *Barden Precision* means not only dimensional accuracy but performance to match the demands of the application.

Your product needs *Barden Precision* if it has critical requirements for accuracy, torque, vibration, temperature or high speed. For less difficult applications, Barden *predictable* performance can cut your rejection rates and teardown costs.

Write today for your copy of Catalog Supplement M1 which gives dimensions, performance and engineering data on *Barden Precision* ball bearings 5/8" O.D. and smaller.

THE BARDEN CORPORATION

49 E. Franklin St., Danbury, Connecticut • Western office: 3850 Wilshire Blvd., Los Angeles 5, California

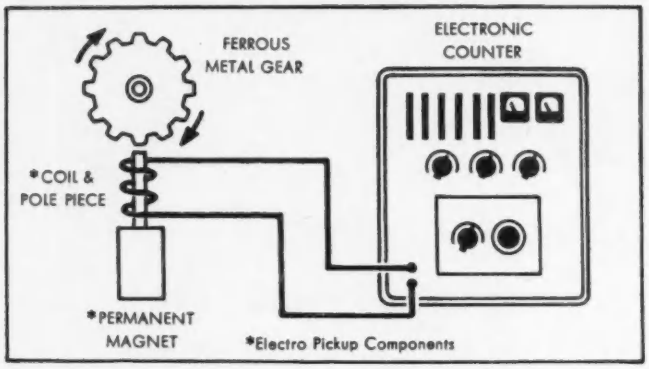
SPECIFY BARDEN PRECISION BALL BEARINGS FOR: INSTRUMENTS • AIRCRAFT ACCESSORIES • COMPUTERS AND RECORDERS • MACHINE TOOL AND TEXTILE SPINDLES • OTHER PRECISION APPLICATIONS

Ideas for your Engineering File

Electro ELECTRONIC EQUIPMENT

MAGNETIC TRANSDUCERS

A precise way to solve your speed measurement problems...



PROBLEM: to measure turbine speeds up to 100,000 rpm

SOLUTION:

a Locate Magnetic Pickup adjacent to the teeth of any convenient gear used in the machine—or add a small bit of magnetic material to a non-magnetic rotor.

b Feed output of Magnetic Pickup directly to electronic counter. Set counter to count for a suitable time—such as 1 second (1/60 minute).

$$\text{RPM} = \frac{\text{Displayed count} \div \text{pulses per rev. (no. of teeth)}}{\text{counting time (minutes)}}$$

Accuracy depends on three factors:

1 Accuracy of the counter (usually ± 1 digit).

2 Length of counting time.

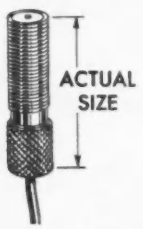
3 Number of pulses per revolution.

Example:

60 tooth gear providing 60 pulses per revolution with a count of 1 sec. (1/60 min.) will produce an accuracy of ± 1 rpm at *any* speed. (counter reads rpm directly with this set-up). If counting time is increased to 10 sec., accuracy will be ± 1/10 rpm.

ELECTRO PRODUCTS LABORATORIES
4501-C Ravenswood, Chicago 40, Ill., LOngbeach 1-1707
Canada: Atlas Radio Ltd., Toronto

Sub-Miniature 3055



¼"-40 Mounting Threads
0.14 oz.

Use to Actuate, Provide Telemetering Data, Indicate, Control, Synchronize

Electronic counters
Relays
Missiles
Motion
Speed
Vibration
Torque
Electric devices
Mechanical operations
Others

8089

Electro ELECTRONIC EQUIPMENT

D.C. Power Supplies

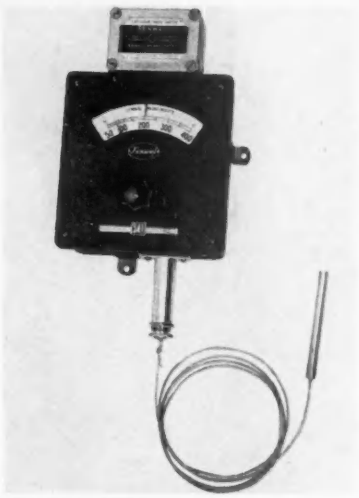
Proximity Pickups

Sonometer

Dynamic Micrometer

Sensing Elements for Control Counting
Speed and Displacement Measurements

NEW PRODUCTS



EXPLOSION-PROOF

This temperature-indicating controller is available in an explosion-proof housing for use in hazardous locations. The box atop the control case contains the electrical snap-switch for modifying the unit.—Fenwal, Inc., Ashland, Mass.

Circle No. **24** on reply card

MULTIPLEXER

With the type 40-101 Plexicoder, signals from up to 90 transducers can be multiplexed at 112 samples per second and converted into duration modulated pulses for telemetering or magnetic tape recording. The new multiplexer is designed for service-free life of 1,000 hours, is shock-mounted, and operates in any position. It weighs 45 lb.—Consolidated Electrodynamics Corp., Pasadena, Calif.

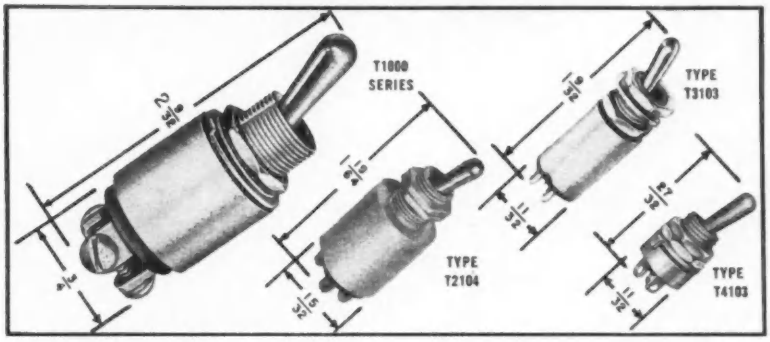
Circle No. **25** on reply card

HETHERINGTON

SWITCHES • INDICATOR LIGHTS • SPECIAL ASSEMBLIES

ENGINEERING NEWS

Say "WHEN" to Toggle SWITCH MINIATURIZATION



Few basic electrical components have been successfully miniaturized with such telling effect as the toggle switch. Hetherington has developed space- and weight-saving cylindrical types with ratings, dimensions, and performance tailored to the critical requirements of airborne and industrial electrical systems. And, thanks to Hetherington's positive cam-roller snap action, even the smallest types carry ratings far greater than their sizes would indicate.

Recent Hetherington developments such as the sub-miniature Type T4103 shown above approach the point where further miniaturization would seem to present more difficulties in mounting than in obtaining adequate switch performance. Although not quite ready for production, field tests of the T4103 have shown great promise for drastically cutting weight while assuring better performance in aviation's toughest jobs.

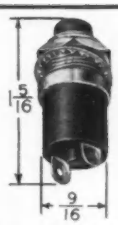
"BILLBOARD" LIGHTS

Make Crowded Panels More Meaningful

Too often the significance of tiny conventional indicator lights is hard to determine at first glance—especially if many are used on one panel. With Hetherington Placard Lights, vital control information can be read directly in terms of symbols, digits, abbreviations, words, or entire phrases engraved on plastic lenses. Two miniature AN3140 lamps boldly illuminate the lettering, thus avoiding delay or errors of interpretation.

In spite of their large (1-3/8" x 9/16") lenses, over 40 Placard Lights fit comfortably in a 9 x 5" area thus simplifying many annunciator-type panels where lights are closely grouped. For details, write for Data Sheet L-3.

8 AMP U. L. RATING ... ½ amp Size and Price



Here's just the push-button switch to dress-up and improve that instrument, appliance or other "black box" now on the drawing table—and with attractive cost and space advantages in the bargain.

For the performance of these B-Series Switches comes mighty close to that of Hetherington's aviation-quality switches in terms of positive "feel," fast and audible snap-action. Normally-open or closed SP-ST types with 8-amp U.L. Approved ratings available with lugs or 6" leads. Send for Data Sheet S-4.

SWITCH PROTECTION "TAILORED"

to humidity
... moisture
... spray
... immersion

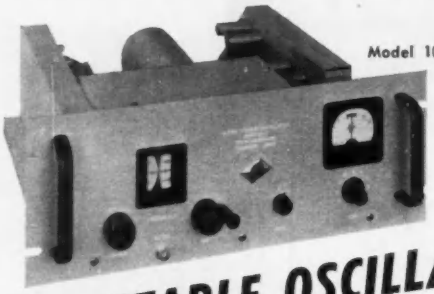
Although the mechanism of every Hetherington push-button and toggle switch is protected by the case against dust and moisture, some special requirements call for additional "climate-proofing." Where the perfect hermetic seal of a metal bellows is not needed, "O" rings, sleeves or boots of lightweight silicone rubber offer inexpensive solutions for most applications as shown by the typical types at right.

"O" RING AT BASE OF LENS ON INDICATOR LIGHT
RUBBER BOOT MOLDED TO HEX NUT—TOGGLE SWITCH
RUBBER BOOT MOLDED TO HEX NUT—PUSH BUTTON SWITCH
METAL BELLOWS HERMETICALLY SEALED TO SWITCH CASE
INTERNAL RUBBER SLEEVE AROUND BUTTON

HETHERINGTON INC. DELMAR DRIVE, FOLCROFT, PA. • 139 Illinois St., El Segundo, Calif.

standard switches for the most specialized requirements

Stability: one part in a billion



Model 101-C

ULTRA STABLE OSCILLATOR

Model 121-A

with Frequency Dividers and Multipliers

Hycon Eastern Ultra Stable Oscillator, Model 101-C, is a one megacycle signal source of proven exceptional stability. It is useful wherever precise time measurements or frequency control are required, as in reinsertion of carrier in suppressed carrier systems, astronomical measurements, navigation systems, geophysics or other critical applications.

Auxiliary highly stable outputs covering the spectrum from sub-audio to microwave can be made available through the use of Hycon Eastern FREQUENCY DIVIDERS, MULTIPLIERS, AND PHASE-LOCKED OSCILLATORS.

Write for Ultra Stable Oscillator Bulletin.

- **FREQUENCY STABILITY:** Drift rate less than 1 part in 10^9 per day after initial stabilization.
- **FREQUENCY:** 1 megacycle, variable over a range of 1 cycle. Available at other frequencies on special order.
- **CRYSTAL OVEN:** Stabilized to better than 0.01°C by temperature-sensitive resistance bridge and high-gain heater control circuit.
- **DISSIPATION IN OSCILLATOR CRYSTAL:** Stabilized at a power level less than one microwatt to insure ultimate stability.
- **2 OUTPUTS:** Sine wave—4 Volts RMS; Pulse—1 Volt.
- **OUTPUT IMPEDANCE:** 250 Ohms nominal.
- **POWER REQUIRED:** 150 Volts, 100 MA, Regulated DC, and 6.3 Volts, 3 Amperes, AC or DC. (Matching Power Supply available).

HYCON EASTERN, INC.

75 Cambridge Parkway Dept. J Cambridge 42, Mass.

ACTUATORS & FINAL CONTROL ELEMENTS

60-CYCLE SERVOMOTOR

This small servomotor responds rapidly to 60-cycle power. It's available either as a unit or as a servo assembly. Size 11.

Characteristics:

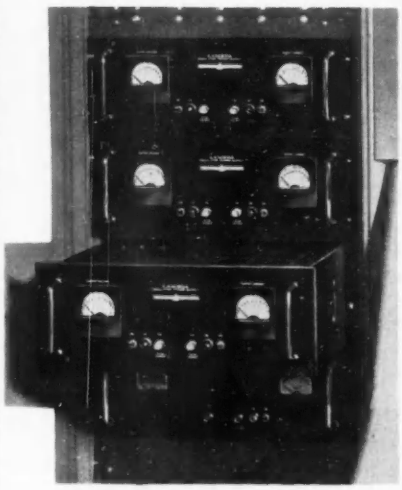
Torque: 1.0 oz-in. (stall)
Acceleration at stall: 59,000 radians per sec^2
Gear ratios: from 1:10 to 1:2,187
Backlash: less than 30 min.
—Daystrom Transicoil Co., Worcester, Pa.

Circle No. 26 on reply card

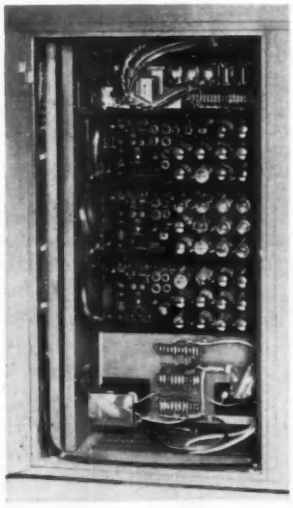
CONTROL VALVE

A double-acting cylinder operates this hydraulic control valve at operating pressures from 60 to 140 psi, using water, oil, or air. The valve controls

Digital Computer Intervention and Display System designed and fabricated by Stromberg-Carlson Company, a Division of General Dynamics Corporation, for the Air Proving Ground Center (ARDC) Armament Division, Eglin Air Force Base. The system is built around the CHARACTRON* Shaped Beam Tube, designed by Stromberg-Carlson for high speed information display and micro-film recording.



C-800 Lambda Com-Pak Power Supplies used in the Eglin Air Force Base installation require only 7" front panel height.



Easy servicing. All wiring, tubes and other components are readily accessible. You can reach them easily, service them fast.

COM-PAK® SUPPLIES SAVE PANEL SPACE

Models through 1.5 amperes
Three voltage ranges: 0-200, 125-325, 325-525 VDC

C-200 series–	200 MA–	5¼" panel height–	from $159.50
C-400 series–	400 MA–	5¼" panel height–	from 244.50
C-800 series–	800 MA–	7" panel height–	from 315.00
C-1500 series–	1500 MA–	8¾" panel height–	from 550.00

Where power supply dependability is vital

Stromberg-Carlson specifies standard Lambda power supplies for Air Force Digital Computer Intervention & Display System

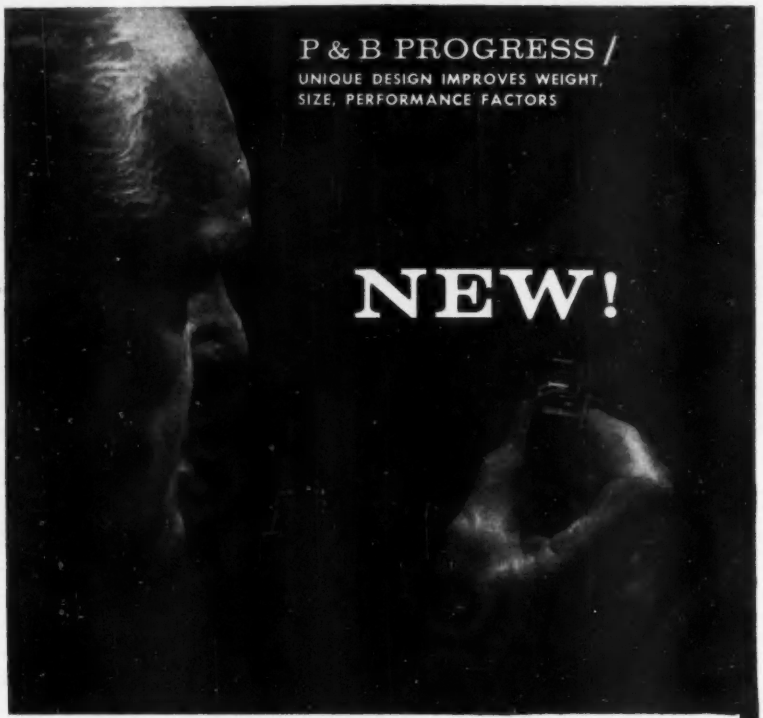
Standard Lambda power supplies are components of the Digital Computer Intervention and Display System associated with the UNIVAC Scientific Computer at the Air Proving Ground Center (ARDC) Armament Division, Eglin Air Force Base, Florida.

Available for immediate delivery, Lambda power supplies from stock are being used in major rocket and missile programs, among other military projects. They are specified also for more industrial and research applications than the ten next-most-popular makes combined.

Send for the current Lambda catalog. It covers the complete new Com-Pak series, as well as other rack, bench and portable models, for all needs through 1.5 amperes.

LAMBDA Electronics Corp.
11-11 131 STREET • COLLEGE POINT 56, NEW YORK
INDEPENDENCE 1-8500 Cable Address: Lambdatron, New York

*CHARACTRON is a trade-mark of Stromberg-Carlson, a Division of General Dynamics Corporation, registered in the U.S. Patent Office.

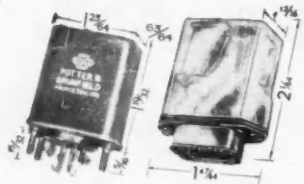


MINIATURE TELEPHONE TYPE RELAY HAS SUPERIOR SHOCK/VIBRATION RESISTANCE

Unusual for a telephone type relay, the MG Series has excellent stability under high shock and vibration conditions. Tests show this miniature, light weight (only 1.2 oz., open) relay withstands vibration of 10g 55 to 500 cycles per second and will operate under shock to 30g according to Mil-R-5757C.

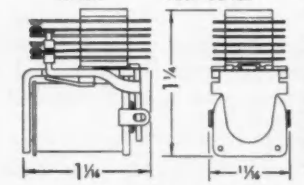
The superior performance of the MG is due in part to its unique single stack construction and to an exclusive hinge design which provides zero heel gap.

Open, dust covered or hermetically sealed, the MG is available with contact arrangements up to 4 Form C (4PDT). It is rated for ambient temperatures of −55°C to +85°C. A high-temperature version with a range of −65°C to +125°C will soon be available. Write or wire today for complete specifications and delivery information.



HERMETICALLY SEALED

POLYSTYRENE DUST COVER



MG RELAY

TERMINALS:
Open Relay: Pierced Solder Lugs.
Contacts: Two #18 AWG wires. Coil: Two #20 AWG wires.
Hermetically Sealed:
Miniature plug-in header with 7, 9 or 14 pins. Multiple Solder header with hook end terminals for three #20 AWG wires.
Polystyrene Dust Cover: Micro Ribbon plug-in type.
Mating receptacle: Amphenol #57-20140 or similar.
INSULATION RESISTANCE: 100 megohms min.
VIBRATION: .065" excursion 10-55 cps. 10g 55-550 cps. upon request.
SHOCK: 30g according to Mil-R-5757C upon request.
TEMPERATURE RANGE: −55°C to +85°C.
WEIGHT: 1.2 ozs. (open) 2.0 ozs. (sealed).
PULL-IN SPEED: Approximately 15 ms at nominal voltage.
DROP-OUT SPEED: Approximately 10 ms at nominal voltage.
CONTACTS: 3/32 silver.
CONTACT ARRANGEMENT: 4 pole, double throw (4 Form C).
COIL POWER: 3 watts max. DC @ 25°C. Continuous duty.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONIC, ELECTRICAL AND REFRIGERATION DISTRIBUTORS

Potter & Brumfield, inc.

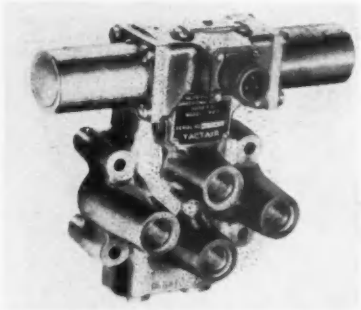
PRINCETON, INDIANA

SUBSIDIARY OF AMERICAN MACHINE & FOUNDRY COMPANY
Manufacturing Divisions also in Franklin, Ky. and Laconia, N. H.

NEW PRODUCTS

lines of 600 to 4,000 psi with extremely rapid response. It is available in two- or three-way types with port sizes of 1, 1½, and 2 in. NPT.—Sinclair-Collins Valve Co., Akron, Ohio.

Circle No. 27 on reply card



FOR ROCKETS

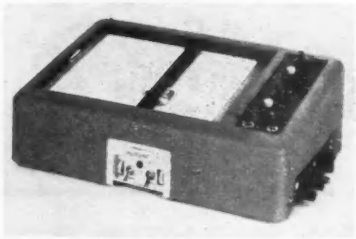
The four-way solenoid-operated selector valve shown features fast operation over a wide range of operating pressures.

Characteristics:

Pressure range: 500 to 3,000 psi from sea level to 70,000 ft.
Operation time: 0.05 sec.
Temperature range: minus 65 to plus 160 deg F.
Leakage: 3 cc per hour
Current drain: 0.5 amp
—Aircraft Products Co., Bridgeport, Pa.

Circle No. 28 on reply card

RESEARCH, TEST & DEVELOPMENT



TIME BASE, TOO

Photo shows new X-Y plotter with built-in time base circuit. It plots any physical or mechanical function which can be reduced to electrical form against time. Five calibrated time

Gene Barber discusses the MAGSENSE

A big step forward in the art of data processing was taken when techniques were perfected to monitor the electrical outputs of sensing devices by sequentially connecting transducer analog output voltages to an electronic level-comparison device. This technique eliminated, to a large extent, errors in human judgment arising from the time-consuming reading of meters and recording equipment —equipment frequently spread throughout a plant. Above all, it permitted alarm-monitoring as many as 10 critical points in a process each second. Thus, 100 points could be checked every 10 seconds although, of course, each point was still checked only once every tenth second.

While this scanning speed is quite adequate for some applications, there is a very real demand today for a much more rapid monitoring of ever-increasing numbers of points. Consider, for instance, the monitoring and control of atomic reactors, or the sensing of critical conditions in aircraft and missile check-out systems.

Today a sampling rate as high as 100 times per second per channel is desired for hundreds of channels. Electro-mechanical scanning devices using vacuum tubes and mechanical switching arrangements can not be made to attain these speeds with reliability. Moreover, such devices are not generally satisfactory for the switching of low-level signals such as thermocouples without individual point preamplification. This, in turn, places the desired reliability in jeopardy.

Attempts to circumvent these obstacles have centered around the notion of replacing mechanical components with electronic or magnetic counterparts. But electronic switches have not displayed the required accuracy or stability to handle the very low-level signals generated by thermocouples without preamplification. Magnetic devices, on the other hand, have demonstrated excellent reliability when handling signal levels as low as 10^{-15} watt, or well below the normal thermocouple output.

The principle of magnetism has therefore been invoked in producing the MAGSENSE, a name coined to identify a particular magnetic alarm monitoring device.

A small magnetic core is provided with a winding connected to a monitoring thermocouple or other transducer. A second winding is biased by a solid-state stabilized power supply to a pre-set threshold level. As long as this threshold level is not exceeded, the core's flux polarity is unaltered. However, should the input current exceed the threshold level, the core flux polarity is reversed to reverse the induced polarity of a voltage in a third winding. This reversal of polarity is the signal indicating an alarm condition.

The possibility of using this output voltage directly to drive an indicator light or alarm device is highly attractive, and success is dependent only upon the Magsense having sufficiently high gain and low equivalent input noise. Such a device has been developed displaying sufficient sensitivity to indicate a 2°F change in temperature.

Gene Barber, Daystrom Systems engineer who specializes in the design of magnetic circuitry, discusses the Magsense.

The Magsense functions continuously at a rate determined either by the line or a separately-generated frequency. An independent core is provided for each input and the total number of channels is limited only by the power supply available to drive them. Thus, for instance, 100 channels sampling at a line frequency of 60 cps will yield 6,000 samples per second as compared with the 10 samples per second produced by the electro-mechanical scanning device mentioned above.

Most important of all, reliability is significantly enhanced because the Magsense uses neither moving parts subject to wear, nor vacuum tubes subject to burnout.

By applying the latest proven techniques, our well-qualified staff at Daystrom Systems is prepared to take single responsibility of assembling and installing a system to meet your needs. We are currently compiling a file of new applications and papers on various parts of systems, both industrial and military. If you are interested in receiving the file and periodic additions, please write us.

DAYSTROM SYSTEMS

Division of Daystrom, Inc., 5640 La Jolla Boulevard
La Jolla, California Telephone GLencourt 4-0421
Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 10, Canada
Export: Daystrom International, 100 Empire St., Newark 12, N.J.

DELAY LINES by TECHNITROL

Technitrol standard or specially-designed delay lines, continuously wound to close tolerances, are extremely compact and very stable. Standard tolerances of these distributed constant delay lines are: on delay, ±5%; on impedance, ±20%. Extremely stable with respect to environmental conditions, they are available cased in epoxy resin or hermetically sealed for military applications.

3½" EPOXY CASE

Standard windings with delays from 0.1 μ sec to 1.0 μ sec and impedances from 560 to 5000 ohms are available in 3½" case and 6" case. This is a stock item.

ED 1000-100

Epoxy resin case with leads grouped at one end. 1 μ sec delay; 1000 ohms impedance; rise time 0.1 μ sec max. This is a stock item.

STEEL CASES HERMETICALLY SEALED

For multiple stick needs and military applications. Completely sealed, potted in foam. Delays are based on stick capacity and type of winding.

DIP-COATED

For economy, any standard winding is dip-coated in epoxy resin. Moisture resistant; stable for temperature range from −25°C to +85°C.

Write for New Catalogs

TECHNITROL
ENGINEERING COMPANY
1952 E. Allegheny Ave., Phila. 34, Pa.

NEW PRODUCTS

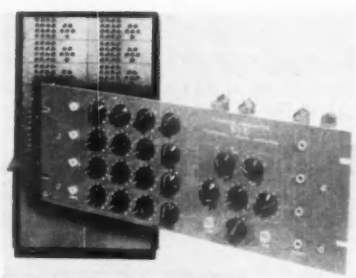
intervals are available, from five to 500 sec.—F. L. Moseley Co., Pasadena, Calif.

Circle No. 29 on reply card

NO WIND TUNNEL?

Aerodynamic heating can be simulated by radiation transfer of heat to a test specimen. An analog computer like the model shown schedules the rate of heat transfer and regulates power input to heating lamps via an ignitron power controller. Wright Field, Sweden's SAAB, and Boeing use computers of this type.—Research, Inc., Hopkins, Minn.

Circle No. 30 on reply card



ANALOG BUILDING BLOCK

The K5-U Universal Linear Operator is an analog unit for continuous real-time computing, high-speed repetitive operation, or single-shot solutions. A computer made up of ten of these units solves linear differential equations of up to those of tenth order. Three-digit decade settings eliminate computing pots and allow direct adjustment of parameters without servo-setting, digital voltmeters, or calibration charts.—Philbrick Researchers, Inc., Boston, Mass.

Circle No. 31 on reply card

ANOTHER NEW LESLIE PRODUCT

ADJUSTABLE PROPORTIONAL BAND Floatless LIQUID LEVEL CONTROL

...with adjustable level ranges up to 0-200"

Here is a new differential pressure-type liquid level control pilot that combines the wide adjustable level ranges in the table shown below with a 2-20" or 7-25" adjustable proportional band.

ADJUSTABLE LEVEL RANGE — INCHES	ADJUSTABLE PROPORTIONAL BAND (INCHES, H_2O)	CONTROL PILOT TYPE
0-40 or 0-87	2-20	LAP
0-30 or 0-91	2-20	LABP
0-200	7-25	LAUP

Maximum Static Pressure — 300 psi

One Knob — Easy Adjustment

A single knob adjustment quickly sets the proportional band where you want it, even while the system is in operation. The liquid level is maintained constantly within that band until you re-set the control pilot for new conditions.

Applications

Leslie-Level-Matic Control Pilots are used in either open or pressurized vessels to control the level of virtually any liquid including water, gasoline, oil and chemical solutions. The new control pilot is particularly useful to maintain constant levels where there are high flow rates through vessels with small cross sectional areas.

Float Cages Eliminated

There are no floats or cages needed for Leslie-Level-Matic Control Pilots, and no torque tube seals, stuffing boxes, or thermohydraulic systems. All of the primary control elements are in one place and may be installed with a fraction of the effort and cost required for displacement-type controllers.

Vibration-Proof, Dependable

All of the dependability factors for which Leslie products are so well-known are incorporated in this new control pilot, as well. Rugged, accurate, stable — it is unaffected by normal vibration or turbulence.

More Information

Send for Engineering Data Sheet describing this new Control Pilot and outlining its principle of operation.

Knob and indicator-type proportional band adjustment permits setting in a matter of seconds.

LESLIE **REGULATORS and CONTROLLERS**

674

LESLIE CO., 211 Grant Avenue, Lyndhurst, New Jersey

*TORQUE WATCH GAUGES

NEW
easy-to-read dials have directional color coding... recessed unbreakable crystals
NEW
special-design ¼" capacity keyless chucks can be hand applied to shafts only ⅛" long. Keyed chucks available on special order
NEW
fist-sized gripping areas are color coded to identify range

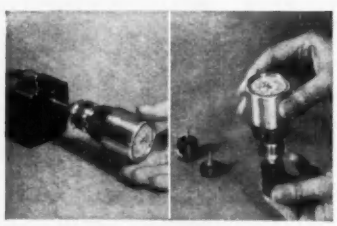
by *Waters*

NOW.....YOU CAN ACCURATELY HAND-GAUGE ALL STARTING AND MOVING TORQUES BETWEEN 0.005 AND 40 OUNCE INCHES!

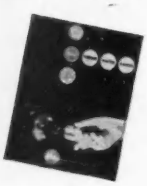
New, improved Waters Torque Watch Gauges put torque measurements on a production line basis. They save time and money by eliminating laboratory "lash-ups."

Simple one-hand operation and easy-to-read dials speed accurate readings. Standard accuracy is ±5% of full scale. Accuracy of ±2% of full scale is available on special order. Any standard one-way 5% gauge may be calibrated to ±1% accuracy at a single point only.

Complete line includes clockwise, counterclockwise and bi-directional models . . . with dials reading in ounce inches or gram centimeters. Special chucks and adapters extend range of application.



SEND FOR BULLETIN AND PRICES on the 38 available models.

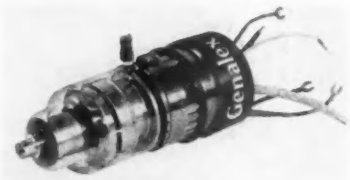


*DESIGN PATENT 177889

Waters **Waters MANUFACTURING, INC.**
BOSTON POST ROAD, WAYLAND, MASSACHUSETTS

NEW PRODUCTS

COMPONENT PARTS



HYDROGEN THYRATRON

A replenisher system which generates hydrogen from titanium hydride pellets makes this hydrogen thyratron last four times longer; the series includes replacements for the widely-used type 5948. A special baffle prevents barium from the cathode from depositing on the grid and reducing the tube's secondary emission. Operates at ambient temperatures from minus 25 to plus 70 deg C.—British Industries Corp., Port Washington, N. Y.

Circle No. 32 on reply card

ADJUSTABLE STOP

Available in two models—0 to 10 and 0 to 40 revolutions—this miniature adjustable limit stop features a single range-setting screw at the end cap capable of adjusting stop rotation continuously from zero to full scale.—Precision Mechanisms Corp., East Meadow, N. Y.

Circle No. 33 on reply card

RUGGED POT

The G-45 rectilinear potentiometer will operate accurately under 20 g's vibration, 100 g's shock, or 275 deg F

STRAIGHT TALK TO ENGINEERS

from Donald W. Douglas, Jr.

President, Douglas Aircraft Co., Inc.

Here at Douglas we're involved in a greatly accelerated missile and space program. This requires one of the most intensive engineering and research efforts in our history.

The problems are great ones as we move into the new dimension of unmanned and manned space vehicles. They require specialists in almost every engineering field. But their solution will result in great benefits not only to our own nation but to all mankind.

If you're interested in tackling these problems with us... in giving your best in an all-out drive to solve them... we're interested in you!

Please write to Mr. C. C. La Vene
Douglas Aircraft Company, Box D-620
Santa Monica, California

NEW!

GREATER...

- OUTPUT
- STABILITY
- ACCURACY

- Multi-column
- Smaller size
- Hermetically sealed

Cox and Stevens

LOAD CELLS

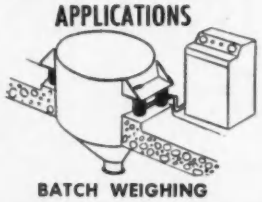
For greater accuracy and stability in all types of weight and force measurement, specify new Cox and Stevens hermetically sealed load cells. Sixteen strain gages in multi-column design provide up to 250% greater output, improved stability and better uniformity between cells. Capacities range from 500 to 200,000 lbs. All cells with 30 feet of special moisture- and chemical-resistant cable in stainless steel jacket.

Cox and Stevens' fifteen years experience in designing and manufacturing load cells, plus dead weight testing facilities which make possible calibration to higher accuracies, assure maximum reliability. Write for technical bulletins.

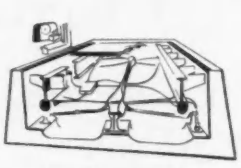
TYPICAL SPECIFICATIONS

1. Recommended Input: ..... 20 volts
2. Change in Output, No Load to Full Load: ..... 1.750 ± .1% millivolts/volt input
3. No Load Output: ..... ± .25% of full load output
4. Output Linearity: ..... 0 to + .20% of full load output
5. Temperature Effect on Cell Output (15 to 115°F): ..... ± .0008%/°F of output at applied load
6. Temperature Effect on No Load Output (15 to 115°F): ..... ± .0013%/°F of full load output
7. Input Impedance at 75°F: ..... 450 ± 1 ohms
8. Allowable Load: ..... 225% of rated capacity
9. Deflection Under Rated Load: ..... Less than 0.003"

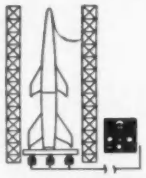
APPLICATIONS



BATCH WEIGHING



PLATFORM SCALES



MISSILE WEIGHING

also Continuous Weighing · Proportioning · Truck, Track, Tank and Crane Scales · Thrust Measurement

53

REVERE CORPORATION OF AMERICA

Wallingford, Connecticut

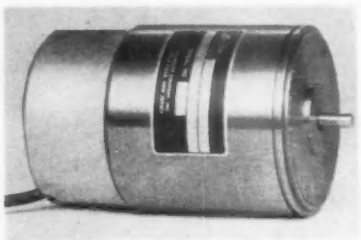
A SUBSIDIARY OF NEPTUNE METER COMPANY

neptune

NEW PRODUCTS

temperatures. Double seals at the actuating shaft protect the interior against humidity and dirt. Range: 0.5 to 12 in.–Servonic Instruments, Inc., Costa Mesa, Calif.

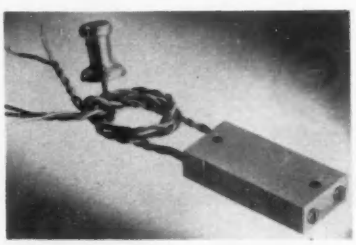
Circle No. 34 on reply card



MAXIMUM ERROR OF 30 SEC

With a maximum error from electrical zero of just 30 sec, this new resolver-type synchro component can serve as a four-wire control transmitter, control differential transmitter, or control transformer. Designed for 400-cps operation, the unit may be modified to operate at either 4,000 or 10,000 cycles. A compensator winding maintains accuracy despite temperature and frequency variations. Weight is 2¾ lb and operating temperature range is from minus 40 to plus 85 deg C.–Kearfott Co., Inc., Little Falls, N.J.

Circle No. 35 on reply card



AFFORDS HIGH RESOLUTION

A new miniaturized trimming potentiometer, the Vari-Trim Model 062-WS, contains two trimming potentiometers, two variable resistors, or one of each, plus a fixed resistor. All are housed in a one-piece anodized aluminum case measuring ¼ in. by ⅜ in. by 1¼ in. Each wire wound element is offered in resistances ranging from 1 to 125,000 ohms. By use of an overwind, up to 250,000 ohms can be furnished. Standard unit has a power rating of 0.4 watt at 50 deg C, derating to zero at 105 deg C. –Con-Elco, Monrovia, Calif.

Circle No. 36 on reply card

A report to engineers and scientists from Lockheed Missile Systems—
where expanding missile programs insure more promising careers.

NEW LAB MEASURES ANTENNA PATTERNS; PROBES OUTER SPACE

A new laboratory at Sunnyvale, California today gives Lockheed scientists antenna patterns, scattering and propagation data, and promises exciting new discoveries in the problems of space communication. Laboratory studies include the effect of upper space on radar and radio signals, the radar pattern presented by space vehicles and missile shapes, and the design of antennas to survive the rigorous environment of the upper atmosphere and hypersonic speeds. Findings could pave the way for communication with manned space ships of the future or for the remote guidance of unmanned space ships.

Research and development studies by Division scientists contribute heavily to the projects that place Lockheed in the forefront of U.S. missile developers. These projects include the Polaris solid fuel ballistic missile, Earth Satellite, Q-5 target ramjet, and X-7 test vehicle. Positions created by expansion on these and still other programs we cannot discuss offer unusual opportunities for advancement with our growing young division. Besides Antenna and Propagation, openings are in **Solid State Electronics, Telecommunications, Instrumentation, Radar and Data Link.** Other openings include **Information Processing, Reliability-Producibility, Ground Support, Flight Controls.** Qualified engineers or scientists may write to Research and Development Staff, Palo Alto 15, California.

Lockheed **MISSILE SYSTEMS**

A DIVISION OF LOCKHEED AIRCRAFT CORPORATION
SUNNYVALE • PALO ALTO • VAN NUYS • SANTA CRUZ • CALIFORNIA
CAPE CANAVERAL, FLORIDA • ALAMOGORDO, NEW MEXICO

Mr. Emmanuel A. Blasi, right, Manager of Antenna and Propagation Department, discusses results of radiation performance after antenna pattern measurements with staff scientist Allen S. Dunbar. Column bearing missile in background is operated automatically from laboratory.

New PRECISION FREQUENCY

STATIC INVERTER SUPPLY

INPUT 28V D.C. ± 10%

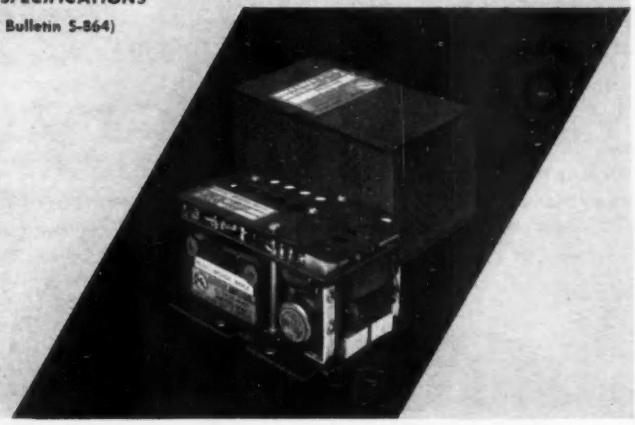
OUTPUT Nom. 115V ± 2% 400 CPS ± 0.01%
1 ø (2- or 3-phase output available)

RATINGS: 30VA 50VA 100VA
Higher ratings available.

APPLICATION:
For gyro wheel supplies and where precise 400 cycle voltages are required in aircraft, radar and missile computers.

FEATURES:
PRECISION OUTPUT FREQUENCY
RUGGED
EXCELLENT WAVEFORM
SIMPLICITY OF CIRCUITRY
FAST STARTING TIME
GOOD VOLTAGE REGULATION throughout an adjustable range
ISOLATED CASE DESIGN
HIGH RELIABILITY
VIBRATION ISOLATED
COMPACT
LIGHTWEIGHT
MILITARY SPECIFICATIONS

(Send for Bulletin S-864)

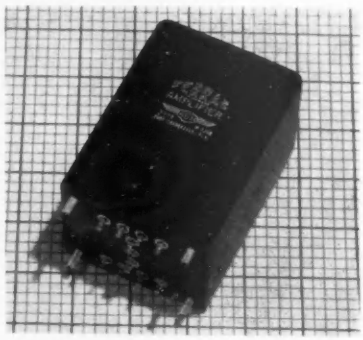


PERFORMANCE SPECIFICATIONS

MODEL NUMBERS	± .01% CPS	SIS 40311	SIS 40511	SIS 410011
	± .05% CPS	SIS 40315	SIS 40515	SIS 410015
INPUT VOLTAGE		28V DC ± 10%		
MAX. OUTPUT POWER		30VA	50VA	100VA
OUTPUT VOLTAGE		115V AC (Adjustable ± 10%)		
OUTPUT FREQUENCY		400 CPS ± .01% 400 CPS ± .05%		
VOLTAGE REGULATION		±1% For Line Variations ± 2% For Load Variations		
FREQUENCY DISTORTION		3% Maximum At Full Load		
LOAD POWER FACTOR		+ 0.5 to − 0.5 Maximum		
MILITARY SPECS.		MIL-E-5400A & MIL-E-5272A		
AMBIENT TEMPERATURE		− 55°C to + 71°C when mounted to heat sink		
VIBRATION		20G 10 to 2000 CPS		
UNIT DIMENSIONS		L5" D 2 7/8" H 2 13/16"	L8" D 2 7/8" H 2 13/16"	L10" D 4 1/2" H 2 13/16"
WEIGHT (Approx.)		2 lbs.	3.5 lbs.	5 lbs.

MA **MAGNETIC AMPLIFIERS INC.**
632 TINTON AVENUE • NEW YORK 55, N. Y. • CYPRESS 2-6610
West Coast Division
136 WASHINGTON ST. • EL SEGUNDO, CAL. • OREGON 8-2665

NEW PRODUCTS



FOR PRECISION

The dc amplifier shown operates directly from 115-volt, 60-cycle power lines without bias or compensating supply. Two properly-matched half amplifiers can keep fluctuations in operating conditions from changing null by more than 0.02 percent. Linear response is to 7.5 dc-volt output to 1,000-ohm loads. It's hermetically sealed.—Airpax Products Co., Fort Lauderdale, Fla.

Circle No. 37 on reply card

CONTROLS SPIN

This angular accelerometer is a precision potentiometer controlling the spin of aircraft and missiles. Model 6-9 is available in ranges from plus or minus two to 4,000 radians per sec per sec. Linear acceleration error is less than 1 percent.—Edcliff Instruments, Monrovia, Calif.

Circle No. 38 on reply card

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DEVELOP	Requires related experience and applicable degree. **Instrumentation and control:** Physicists and EE's for design and development of advanced design vacuum tube, transistor, and/or magnetic amplifier control and instrumentation components. Design and analysis on reactor control systems, using stability and transient response techniques. **Fuel elements:** Metallurgists for R&D on nuclear fuel materials, including radiation effects, evaluation of uranium and thorium alloy, and ceramics. Also for mechanical fabrication development for these materials. **Nuclear fuel reprocessing:** Inorganic and physical chemists for developmental studies and experimental work. Experience with radio-active materials and high temperature processes desirable.
DESIGN	Senior openings. Degree required. Nuclear experience preferred but not essential. **Control mechanisms:** Control and safety rods, drives and allied tooling. **Reactor core components:** Moderator cans, fuel elements, core supporting structures. **Machine design:** Heavy mechanical. **Electrical:** Reactor control and power systems. **Process systems and equipment:** Pumps, Heat transfer equipment. **Facilities:** Mechanical systems. **Process instrumentation:** Reactor, auxiliary, and control systems.

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New programs add to years-ahead backlog

Atomics International has built and is operating two power reactors—the Sodium Reactor Experiment and the Organic Moderated Reactor Experiment. Central station power plants based on these reactor concepts are in the planning stages right now. In addition, AI has just begun an advanced power reactor study for Southwest Atomic Energy Associates, a group of 15 investor-owned utility companies.

AI is expanding overseas operations. With 5 foreign reactors already in operation or being built, AI recently signed agreements with ASEA of Sweden, which has offices in 50 countries, and DEMAG of West Germany, with whom AI formed the new company, INTERATOM, in Duisburg, West Germany.

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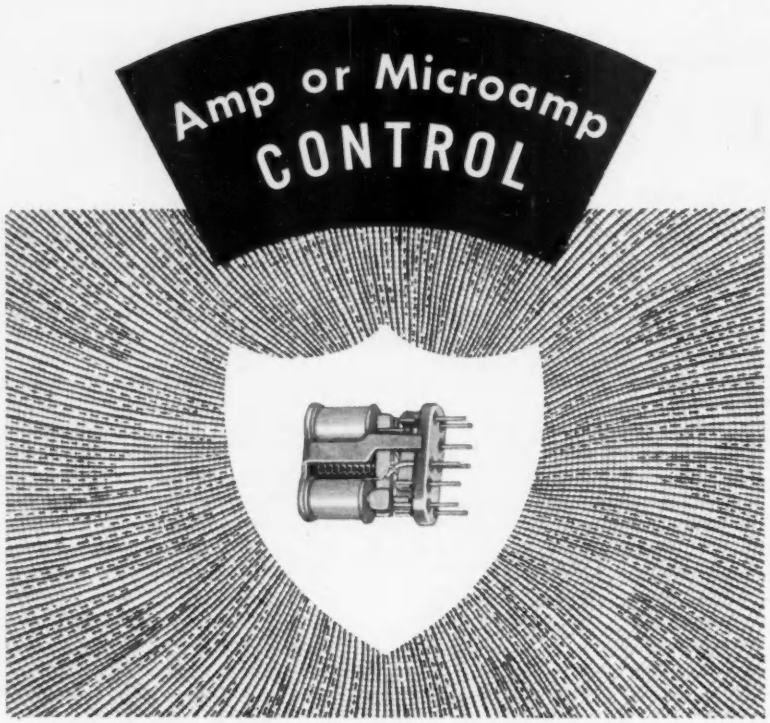

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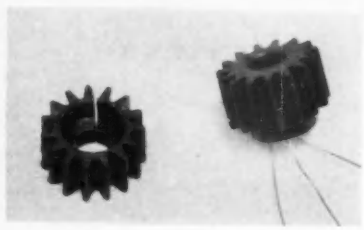

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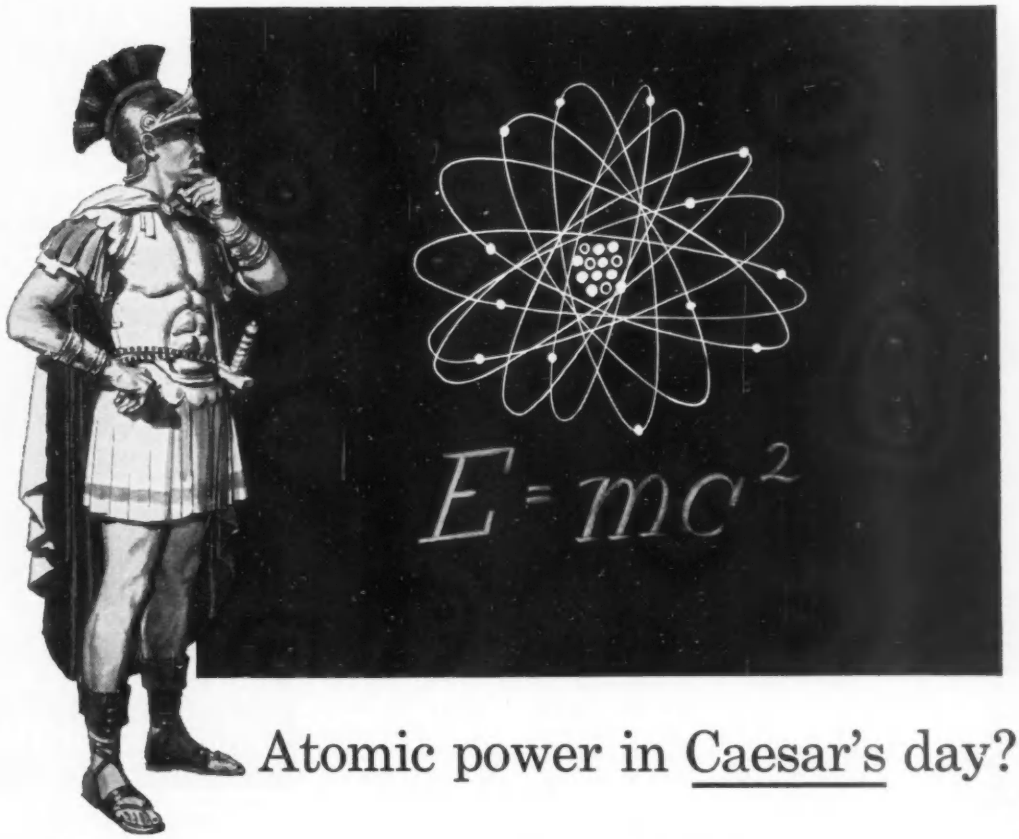
Circle No. **40** on reply card

TAPE DUPLICATOR

The combination tape punch and tape duplicator shown here can punch out 900 lines per minute. The tape punch allows the operator to set up one eight-hole line at a time on illuminated pushbuttons; co-ordinating the punch with the tape reader converts the machine into a tape duplicator which operates automatically.–California Technical Industries, Belmont, Calif.

Circle No. **41** on reply card



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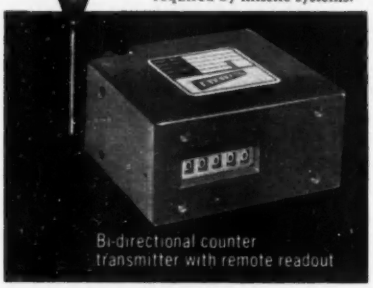

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WHAT'S NEW

[Continued from page 55]

up. The rise reported is almost negligible (3.6 percent from November 1957 to January 1958) compared with the descent (27 percent between July and November 1957), but it is observable under the economist's microscope, and that is what matters.

The feeling now among McGraw-Hill economists is that the last quarter of 1958 will be better for the machinery field than the last quarter of 1957. Significantly, the biggest sales increase (49 percent over the level as of the end of February) is forecast by the unluckiest victim, the metalworking machinery group; and, again significantly, a decline is anticipated by the pump and compressor makers, who got off relatively free in the first quarter.

• **Over the hump?**—Into all these predictions, the McGraw-Hill economists have tossed the conclusion that the recession as a whole has shot its wad; and this makes it interesting from still another standpoint, albeit a negative one. Of the three recessions since the war, this one is the least eccentric. That is, it is just another recession not worse (as far as employment goes, at least) than the one of 1949-1950, but more formidable than the recession of 1954.

It is a fact that unemployment has hit a dangerous high; in February the out-of-work figure was more than twice the 2.5 million reported for last October, normally the year's low point. But it is not as bad as it seems, the experts say. First of all, today there is a larger number of employables, and a larger number of employed; and second, a change in the method of reporting unemployment makes present figures about 200,000 higher than the method used before 1957.

Of course, if there is any further dip in the industrial production index, the recession could become the worst one of the post-war years; but this is viewed as unlikely by practically all observers. In fact, one out of five manufacturing companies in a survey of 176 conducted by the National Industrial Conference Board showed gains in new orders and billings during January. Some of these companies said that their new orders have already hit bottom, and others, that they were expected to sometime in the first quarter of this year. Only six companies did not expect recovery until the first quarter of 1959 or later.

• **R&D expenses soaring**—Another healthy sign is that design and development companies are continuing to

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put out larger amounts of money for research.[2] This work is now on such a large scale that "it is something new for any economy, and many companies have only begun to explore its possibilities."

In 1953, for example, outlays for private research totaled $3.7 billion; last year they hit $7.3 billion. And if government, university, and foundation expenditures follow suit—they amounted to $3 billion in 1957—the total could easily reach $15 billion by 1960. It probably will, too, if enough companies go along with what a few are already doing, and not attempt to strap R&D budgets to sales outlooks. One of these few is Consolidated Electrodynamics, whose R&D investment in 1957 came to $3,971,042 (13 percent of sales).

Said CEC about this departure: "The development program was not reduced in proportion to (a) revised sales outlook because it was felt that the potential of a number of new products . . . was sufficient to justify some sacrifice of current profits to insure their early release to production."

Magnetics, Inc., is following a similar logic. President Arthur O. Black told Magnetics' shareholders: "Fixed costs in the research, engineering, and marketing functions were not reduced with the reduction in our anticipated sales, because it was felt that such reductions in costs would not offset the damage that would result to our future ability to exploit our developments in these areas."

• **Conviction grows**—That this is more in the realm of probability than mere possibility is shown by another McGraw-Hill study:[4] 54 percent of all companies replying to an questionnaire last fall said they will spend about as much on research in 1958 as they did in 1957, 47 percent said they expect to spend more, and only 5 percent said they will cut back in this area.

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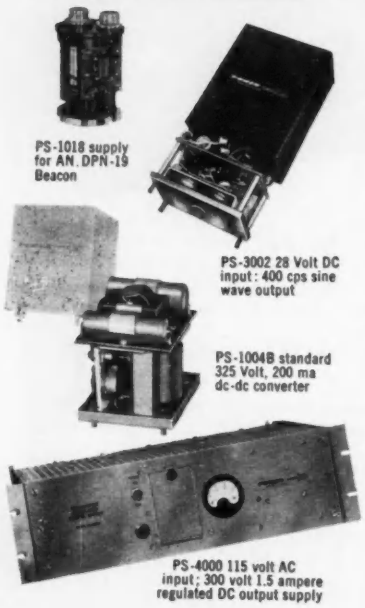

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WHAT'S NEW

IMPORTANT MOVES BY KEY PEOPLE

Assembly Products promotes a new face at Aeronutronics

George J. Crowdes, the new chief controls engineer of Assembly Products, Inc., came to the company last August from the B. F. Goodrich Co., where he had been a development engineer. Before that, he was with Simplex Wire & Cable Co. and Dennis Chemical Co.

Ford Motor's Aeronutronic Systems, Inc., has named **Joseph V. Charyk** director of missile technology, a broad-gage position that carries responsibility for the company's weapon system and aeronautical operations. These are carried out at Aeronutronic's headquarters at Glendale, Calif., and at its experimental and test facilities at Newport, Calif. Charyk is one of the country's leading authorities on aerodynamics and propulsion. At the same time, **Montgomery H. Johnson**, formerly director of Aeronutronic's Nucleonics & Physics Laboratory, becomes director of advanced research. He is a fellow of the American Physical Society.

Vincent Moore, who has been assistant chief engineer, design, at the Wright Aero Div. of Curtiss-Wright Corp. since 1955, has joined the Hamilton Standard Div. of United Aircraft Corp. as chief of design. Moore started with Curtiss-Wright in 1936; prior to 1955, he was director of development for reciprocating engines.

Schulze advances in AMF Consolidation; Selas appoints

With the consolidation of American Machine & Foundry's Nuclear Engineering Laboratory into its Atomics Div. (headquarters at Greenwich, Conn.), **Otto A. Schulze** advances from section manger of the laboratory to manager of the parent division. Schulze joined AMF in 1955 as a nuclear engineer; before that year he was with Argonne National Laboratory as chief physicist on the experimental boiling water reactor (EBWR) project, a design engineer for Allis-Chalmers Mfg. Co., and a student at the Oak Ridge School of Reactor Technology.

Selas Corp. of America has named **C. Glen Bigelow Jr.** director of research, a new position. Bigelow comes

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to the Dresher, Pa. process engineering company from American Machine & Foundry Co., where most recently he was new products secretary in the New York headquarters. He has also been associated with Loftus Engineering Co. and U. S. Gypsum Co.

The TC Components Div. of Brubaker Electronics Co., a subsidiary of Telecomputing Corp., has a new general manager. He is **T. Ross Welch**, an authority on relay design and development who was formerly director of R&D for Elgin Watch Co.'s Electronics Div. at Burbank, Calif. He has also been chief engineer of Leach Relay Co. and head of his own electronic components concern, Neomatics, Inc., which in 1954 was merged into Elgin. Welch is responsible for the development of the electromechanical force–stroke machine for predicting and calculating relay performance.

Metrix and Fairchild import; Eitel-McCullough promotes

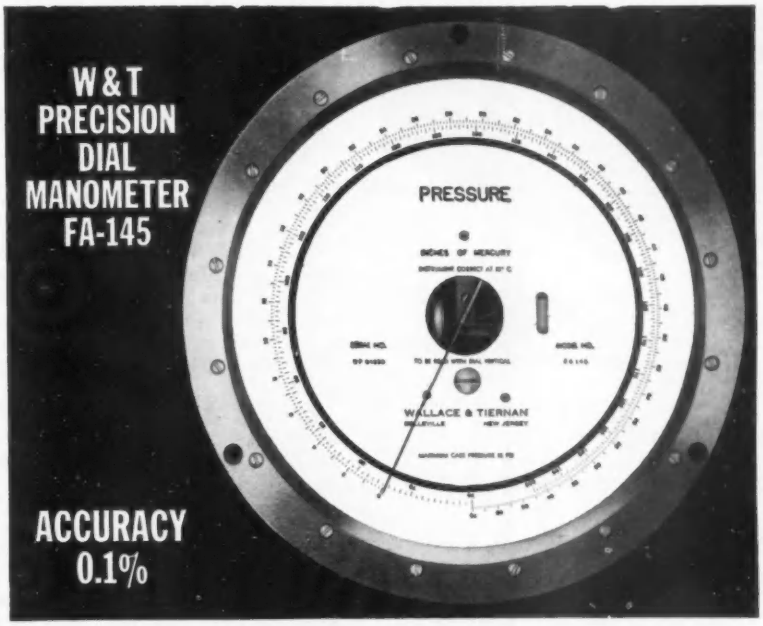
The new Metrix Corp. (CtE, March, p. 52) has brought in **Edgar J. Jones** from the Electronics & Instrumentation Div. of Baldwin-Lima-Hamilton, where he was chief engineer, to be vice-president for R&D. An authority on strain gages, Jones was vice-president of Ruge deForest, Inc., when that company was purchased by B-L-H. He was one of the first to use a bonded-wire strain gage as a measurement tool.

Paul D. Williams has been named assistant director of research for Eitel-McCullough, Inc. He has been with E-M since 1942, first as a chemist in the Research Laboratory, then as chief chemist, and (since 1955) as special assistant to the director of research. He is a fellow of the American Institute of Chemists.

E. M. Baldwin, named general manager of the neophyte Fairchild Semiconductor Corp. (CtE, Dec. '57 p. 166), comes from Hughes Aircraft Co., where most recently he was manager of product engineering. Before joining the Hughes Semiconductor Div. in 1953, Baldwin was asistant director of the Nuclear Research Center at Carnegie Tech.

Industry gains Harvard prof; Eimac loses an R&D engineer

Lester Hogan is leaving Harvard University, where he is professor of applied physics, to follow **John T. Hickey** as manager of Motorola's



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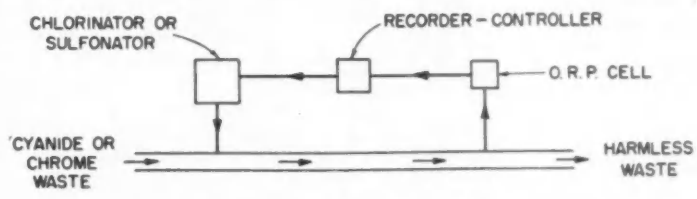

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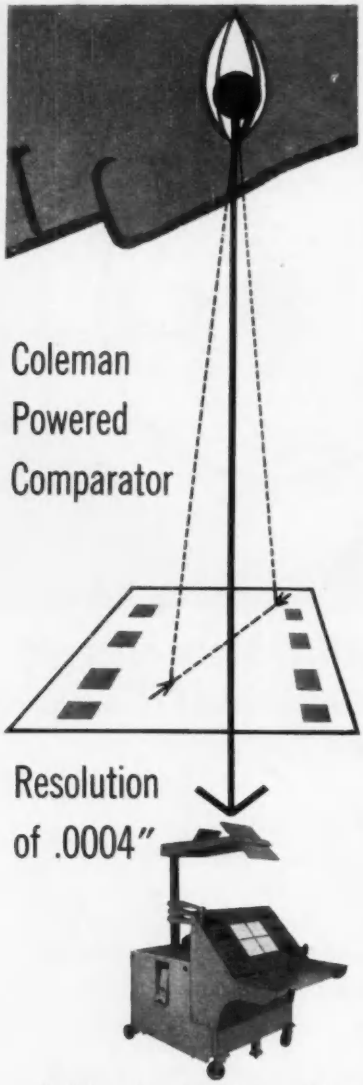

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WHAT'S NEW

Semiconductor Div. in Phoenix, Ariz. Hickey, who advances to the company's corporate staff in Chicago as assistant to the president for long-range planning, went to Phoenix in 1955 to form the division which he now leaves to Hogan. Both appointments, said Motorola officials, reflect "the evolution of the solid state art to a point of highly complex technology at which scientific orientation and administration have increasing significance."

Alfred J. Thompson, formerly senior electronics research physicist at Eitel-McCullough, Inc., has joined the Cascade Research Div. of Monogram Precision Industries, Inc., as an R&D engineer. In his new position he will report directly to **Ronald Soohoo,** head of analytical research.

E. E. Saloum is the new chief engineer of Snap-Tite, Inc., the Union City, Pa. quick-connect coupling maker. Before joining Snap-Tite in 1955, Saloum was with Aero Supply Mfg. Co. and the Chance Vought Div. of United Aircraft Corp.

A reorganization of the transistor plant staff of GE's Semiconductor Products Dept. has resulted in several new positions. Among them: manager of quality control, manager of materials and inventory control, and manager of manufacturing engineering. Filling them are, in the same order, **Triest J. Cappello,** most recently the department's quality control supervisor; **Fred J. Feller,** formerly supervisor of materials and inventory control; and **W. Jesse Harber Jr.,** whose last position was specialist in manufacturing engineering methods.

In the Semiconductor Products Dept. itself, **Sydney O. Johnson,** formerly supervisor of germanium transistor engineering, has been promoted to manager of transistor advance and design engineering, and **Martin E. Clark,** who has been supervisor of silicon rectifier engineering, has been advanced to manager of transister product engineering. The increasing size of the transistor engineering staff is said to be responsible for the two managerships. Johnson joined GE in 1951, Clark in 1948.

Obituary

H. Sherid Garrett, 42, manager of the Application Engineering Dept. of Moore Products Co.; Feb. 27, of a coronary attack. He was the author of a two-part article for CONTROL ENGINEERING on the use of pneumatic relays for industrial control (CtE, Jan. '58, p. 103, and March '58, p. 94).

An Engineer Speaks Out...

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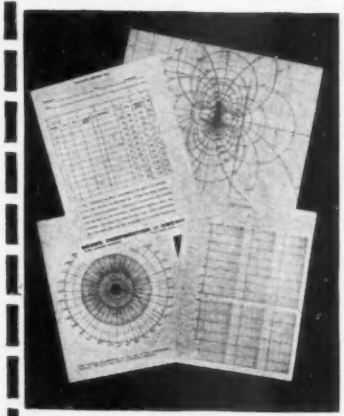

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(100) SUPERVISORY CONTROLS. General Electric Co. Bulletin GET-2738, 20 pp. Describes the operation and application of supervisory control equipment for selective control and automatic indication of electrical apparatus between centralized control points and a number of remote locations.

(101) FEED WATER REGULATOR. Bailey Meter Co. Product Specification M85-1, 4 pp. Offers operational and application data on a thermo-hydraulic feed water regulator for use on small boilers. A two-color sectional drawing shows a typical installation. Tables list sizes, weights, and overall dimensions.

(102) 60 MEGACYCLE NMR. Varian Associates. Data Sheet INS-1301. Lists the advantages of the company's new 60 megacycle NMR Spectrometer and provides four illustrated examples of chemical application of the new technique. Illustrations compare 25-, 40-, and 60-megacycle recordings.

(103) NEW FLOWMETER DESIGN. The C-Mar Corp. Bulletin 5010, 4 pp. Describes a new industrial flowmeter of the area flow type. Section on operating principle shows how the meter uses a tapered vertical orifice rather than conventional tapered tube.

(104) HIGH CURRENT AMMETER. Sensitive Research Instrument Corp. Specification Sheet 2, pp. Covers physical and electrical characteristics of a new direct reading dc ammeter for handling currents up to 100 amp. Photo of unit with back removed shows internal construction.

(105) PACKAGED CIRCUIT. VecTrol Engineering, Inc. Bulletin 101-L, 4 pp. Provides a detailed description of a packaged thyratron for regulating up to 10 kw. Schematic diagrams show alternate applications with one half-wave or two full-wave thyratrons.

(106) PLANT STREAM ANALYSIS. The Perkin-Elmer Corp. Bulletin, 12-pp. Entitled "Automatic Plant Stream Analysis by Gas Chromatography," this bulletin describes the Model 184 Process Vapor Fractometer. It covers the design and operation of three basic units: sensing unit, programmer, and recorder. Installation requirements are also stated.

(107) SIMPLIFIED PROGRAMMING. George A. Philbrick Researches, Inc. Technical Bulletin K5-U, 4 pp. Covers the operation and application of the Model K5-U Universal Linear Operator, an analog computer component which accepts up to four input voltages, applies a weighing factor to each, and obtains the sum in one of several forms.

(108) CAPACITANCE BRIDGE. Electro Measurements, Inc. Catalog Sheet C-15, 4 pp. Deals with electrical and physical specifications of the Model 270 Capacitance Bridge, a wide-range portable instrument offering accuracies within 0.1 percent.

(109) SELENIUM RECTIFIERS. Vickers, Inc. Bulletin EPD 3116-1, 48 pp. Well illustrated with photos, charts, drawings, and performance curves, it provides detailed information on construction, performance, applications, and installation of a new line of grain-oriented selenium rectifiers.

(110) CHROMATOGRAPH APPLICATION. Beckman/Process Instruments Div. Application Data Sheet GC-4203, 2 pp. Gives detailed information on the use of gas chromatography to optimize yield by the continuous analysis of all im-

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portant gas streams within a natural gasoline plant.

(111) HYDRAULIC CYLINDERS. The Oilgear Co. Bulletin 71000, 8 pp. Covers the design features and dimensions of a new line of 2,000-psi double-acting hydraulic cylinders. Classified by mounting means, these include foot lug, center lug, front flange, rear flange, and clevis mounted units.

(112) PRECISION GYROS. Kearfott Company, Inc. Bulletin, 6 pp. Provides performance data on the company's directional gyros and three-gyro stable platforms. Graphs show warm-up characteristics, long term accuracy, and day-to-day drift characteristics.

(113) PYROMETERS. The Pyrometer Instrument Co., Inc. Catalog No. 175, 8 pp. Includes descriptive and technical data on a complete line of pyrometers, covering optical, micro-optical, radiation, immersion, surface, and indicating types.

(114) FREQUENCY METERS. Beckman/Helipot Corp. Data Sheet 1289, 4 pp. Offers complete details on a new, self-contained, 400-cps frequency meter. Photos and dimensional drawing of five basic models, standard specifications, and a discussion of circuitry are included.

(115) SPEED CONTROL. U.S. Electrical Motors Inc., Booklet No. F-1952, 8 pp. Contains useful application information on controlled speed systems. Systems described apply to basic handling processes such as mixing, filtering, conveying, and proportioning.

(116) TRANSISTOR DATA. General Electric Co. Brochure No. ECG-292, 4 pp. Gives complete specifications and a number of graphs characterizing the performance of two germanium alloy junction signal transistors for low to medium power applications.

(117) LOAD MEASURING. Leeds & Northrup Co. Data Sheet ND46-20(1), 4 pp. Presents concise data on the use of Speedomax-G indicators and recorders for measuring pressure, force, tension, and weight using load cell transducers. Includes installation photos of typical industrial applications.

(118) O-R-P MEASUREMENT. Fischer & Porter Co. Catalog 17B100, 4 pp. Describes a new O-R-P cell and a potentiometer-type recorder for measuring, indicating, and recording oxidation-reduction potential. Tells how electric, electronic, or pneumatic control functions can be added for automatic control of batch or continuous processes.

(119) DC POWER SUPPLIES. NJE Corp. Catalog, 16 pp. Covers over 900 power supply models, many of which have been completely redesigned. Each of six catagories contains complete price information, formulas, tables, diagrams, and application data.

(120) INFRARED ANALYZERS. Beckman/Process Instruments Div. Bulletin IR-4005, 6 pp. Describes the operation and application of two new IR Analyzers: the Model 15-A, for continuous laboratory and pilot plant analysis; and the Model 21, for continuous process stream analysis.

(121) WEB GUIDE CONTROL. The North American Manufacturing Co. Bulletin 2-001, 8 pp. Covers operating principles and typical installations of an hydraulic web guide control system. Photos illustrate a variety of edge detectors, relays and regulators, used in the system.

(122) DEWPOINT CONTROL. Ipsen Industries, Inc. Bulletin DC-58, 2 pp. Tells how this company's Dewtronic and Carbotronic instruments provide automatic control of dewpoint and carbon potential in endothermic type atmospheres such as are used in various heat treating processes.

(123) TEMPERATURE CONTROL. Illinois Testing Laboratories, Inc. Bulletin No. 3885, 6 pp. Describes the Alnor Protroller, an indicating-controlling pyrometer featuring compact design. Includes complete specifications, typical wiring diagrams, and application data.

(124) LATCH RELAYS. Clark Controller Co. Bulletin 7305-PML, 4 pp. Outlines the principle features of a new latch relay, and pictures nine standard models with from two to 10 poles. Tables show the number of circuits available and list standard dimensions.

(125) BREADBOARD GEAR. Sterling Precision Corp. Catalog, 12 pp. Covers a complete line of servo breadboard components, including spur and bevel gears, cam assemblies, couplings, hangars, limit stops, etc. Some typical kits are also described.

(126) TEMPERATURE CONTROL. Fenwal, Inc. Bulletin MC-157, 4 pp. Describes Fenwal's Thermoswitch temperature-control systems. Included are complete construction details and six basic design configurations.

(127) OVERHEAT DETECTORS. Fenwal, Inc. Brochure MC-155, 8 pp. Contains a complete description of the operating characteristics of a new fire and overheat detection system for installation in aircraft. Graphs and circuit diagrams are used to illustrate the chief advantages of the system.

(128) VERSATILE DATA LOGGER. Fischer & Porter Co. Catalog 30A1200, 6 pp. Outlines many industrial applications of the company's data-reduction systems and summarizes the principal features of the Series 1200 Industrial Data Logger and Alarm Scanner.

(129) LAMINATED PLASTICS. Taylor Fibre Co. Catalog, 8 pp. Provides photos, descriptions, a table of engineering data, and a selector chart to assist design engineers in selecting and applying laminated plastics and vulcanized fibre.

APPLICATION LITERATURE

NOTE: To receive any of the following items, the reader should write directly to the manufacturer at the address given.

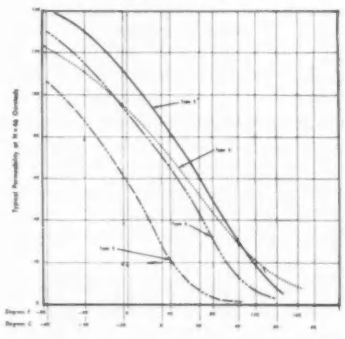
VENTURI METERS. Builders-Providence, Inc., 345 Harris Ave., Providence 1, R. I. Engineering Bulletin 110-P1, 32 pp. This one should prove useful to readers in the process field. A comprehensive technical bulletin, it describes various types of venturi tubes, their recovery characteristics, the formulas that determine their design, and typical applications. Detailed installation instructions, as well as a short discussion on the economics of venturi metering, are also provided.

Four pages, illustrated with isometric drawings, cover a variety of accessories. These include straightening vanes of the sector and multiple-tube types, flushing devices for continuous or intermittent service, vent cleaners, air chambers, condensing chambers, and sealing chambers for metering corrosive liquids.

Other illustrations include diagrammatic sketches, comparison charts and graphs, installation drawings, dimensional data, and capacity tables.

ALLOYS AVAILABLE. The Carpenter Steel Co., 3059 West Bern St., Reading, Pa. This 64-page bulletin, entitled "Carpenter Alloys for Electronic, Magnetic, and Electrical Applications", provides a wealth of information for the design engineer. Technical information on each alloy covers magnetic properties, physical constants, mechanical properties, heat treatment, and machinability. Types mentioned include high permeability alloys, magnetic core iron, temperature compensator alloys, low expansion and glass sealing types, etc.

The booklet is illustrated throughout with 34 useful graphs and an assortment



of tables and photos. The graph above, taken from page 37, illustrates the temperature vs. permeability characteristics of several types of an alloy called "Temperature Compensator—30".

Other features include a page of typical electrical symbols, and a two-page glossary of terms.

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ABSTRACTS

Nonlinear Integration

From "A Nonlinear Integrator for Servomechanisms" by J. C. Clegg, University of Utah. AIEE Transactions Paper No. 58-10, presented at the AIEE Winter General Meeting, New York, N. Y., Feb. 2-7, 1958.

Integration in the forward part of a servomechanism loop is known to reduce steady-state error. However, the time delay in linear integrators poses a problem. Each linear integrator used introduces a 90-deg phase lag, so it takes only two to make a basically unstable system. This paper describes a nonlinear electronic integrator that effectively eliminates this delay problem. Not only does it improve system stability, but it does so without sacrificing any of the desirable qualities of integration.

For simplicity the author considers a common electronic integrator circuit described by the equation

$$e_o = \frac{-1}{RC} \int e_i \, dt$$

The addition of two diodes to this circuit produces a nonlinear integrator for positive input voltages. The diodes are arranged so that as long as the input voltage is positive, the device will continue to satisfy the above equation. As soon as the input voltage starts to become negative, however, one of the diodes conducts and shorts out a series resistance, causing the gain of the amplifier to approach infinity. Almost instantly, this resets the output to zero. The second diode prevents the output voltage from going positive. A second arrangement uses two such nonlinear integrators in parallel for positive or negative input voltages. Here the output voltage is reset to zero whenever the input voltage changes polarity.

Similar devices could be developed for electrical, mechanical, and hydraulic systems as well.

On Standardized Testing

From "Dynamic Response Testing of Process Control Instrumentation, Part I—General Recommendations", prepared by the ISA Committee on Dynamic Testing. RP 26.1—1957. Available from the Instrument Society of America, Pittsburgh, Pa. 50 cents for members, 75 cents for others.

This first of a series of recommended practices for dynamic testing of measurement and control equipment provides general recommendations applicable to all dynamic response test work. It starts by reviewing some of the factors that must be considered in tests of this nature, e.g. the use of data, component interaction, nonlinearity, and power supply performance, then goes into recommended tests, equipment, and procedures. Block diagrams illustrate a generalized dynamic test setup and a typical circuit for generating a step signal. A short glossary defines many of the terms used and does not conflict with ASME Standards 105 or 107.

The committee plans to issue four additional standards offering more detail on specific test procedures.

Excerpts From NACA Report

From the "Forty-third Annual Report of the National Advisory Committee for Aeronautics — 1957" NACA Headquarters, Washington, D. C.

The following excerpts, taken verbatim from the committee's administrative report to Congress, cover some of the recent NACA activities in the fields of automatic control and instrumentation. Ed.

On automatic control of missiles . . .

The unmanned aircraft, or missile, depends upon self-contained control devices to provide it with stability and to control its direction of flight. These control systems, because of the growing need to fly higher and at great speeds, are very complex and expensive. The NACA's automatic control research in the missile field has concerned itself with simplification of stabilization and guidance systems, and with improved means of analyzing and optimizing complex controlling networks under realistic flight conditions such as turbulence in the atmosphere and electronic interference in radar guidance information.

Studies at the Langley Laboratory to establish simple stabilization and control systems for missiles have led to the consideration of on-off or flicker controls, which are momentarily deflected and returned to neutral to correct for errors in a missile's course. Control system theory for nonlinear control techniques of this nature show that flicker controls can maintain a desired missile flight path with mini-

mum use of the controls and with minimum deviations from the desired path. This is accomplished by a particular control switching sequence. An analytical method for determining such a switching criteria, and mathematical technique for analyzing such discontinuous control systems have been developed.

In another Langley Laboratory study, concerned with simplification of missile control and guidance systems, advantage was taken of certain nonlinear aerodynamic characteristics as a means of providing an on-off control system for adjusting a missile's flight path. Results of studies of the above type have been encouraging enough to justify a missile trajectory study of the final phase of target interception with simplified schemes of missile guidance and control. It has been shown that simplified control techniques can provide accurate flight path control, and in addition both the power required and the size of the power unit to actuate the controls may be less than that for other more conventional control techniques.

When missiles are required to operate over broad ranges of speed and altitude, correction of flight path errors require different control deflections for various flight conditions. The required flight path is usually maintained by a complex gearing system to vary the control surface deflections as a function of flight speed and altitude. Studies of ways and means of simplifying this gearing problem have been made at the Langley Laboratory. . . .

At the Ames Laboratory, studies were undertaken to develop an analytical method for the design of control systems for two types of guidance that would provide a missile with the best probability of hitting the target. It was shown that exact analytical solutions may not be feasible; however, approximate solutions can be obtained for an optimized control system by means of a combination of analytical and electronic computer studies. The guidance systems considered were beam rider and homing. In the first system the movements of the target airplane are followed by the electronic beam of a radar device much as the target might be followed by a beam of a searchlight. The missile attempts to fly along this beam to the target. In the homing system, the missile contains its own guidance. Information on target position with respect to the missile is obtained through a tracking radar carried in the missile. A com-

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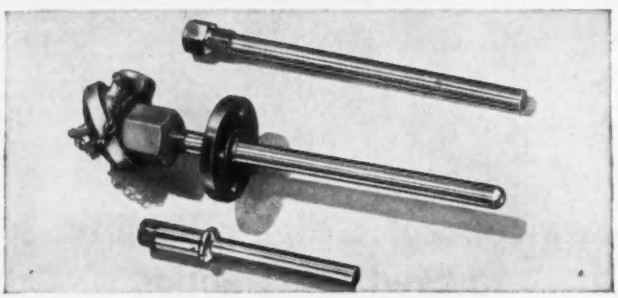

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ABSTRACTS

puter in the missile uses the target information and missile flight information to provide signals to the controls.

Recently, because of their application both to missile guidance systems and to airplane armament firing control systems, considerable attention has been given to optimization techniques for systems subjected to disturbances. A mathematical technique has been developed at the Ames Laboratory for optimizing control systems subjected to random disturbances. The method can be used to study cases where the statistical characteristic of the disturbance is either stationary, which is to say, does not vary with time, or nonstationary, that is, varies with time.

On power plant controls . . .

Liquid propellant rocket motors have been characterized by long development and "debugging" programs. Much of the costly and time consuming procedure is devoted to the redesign of previously satisfactory hardware in order to eliminate unanticipated "chugging" or rocket motor instability. NACA research in the field of rocket dynamics and controls has indicated that paper designs can be translated directly into successful rocket motors if effects of rocket motor component dynamics are properly considered. . .

In an NACA controls research project, a basic rocket system, consisting of a propellant tank, pipe lines, pump, injector, and combustion chamber, was simulated on an analog computer. It was shown that the dynamic behavior of each component has an effect upon the propellant pressure required for stability. The reason for unsuccessful scaling of rockets to either smaller or larger sizes becomes apparent, as it is shown that component dynamic characteristics do not vary proportionately with size. Proper attention to selection of components can eliminate resonances that lead to instability, and increased propellant flow velocities can substantially reduce propellant pressure required for stability. Analog computer simulation of the rocket system prior to assembly of the physical components can greatly reduce development time and cost. . .

Instrumentation research has resulted in new automatic data recorders and data reduction techniques, a new mass-rate flowmeter for rocket propellants, a lithium fluoride scintillating dosimeter for measurement of ionization radiation, and advanced thermocouple techniques.

NEW BOOKS

Educating Management

A MANAGEMENT GUIDE TO ELECTRONIC COMPUTERS. *William D. Bell. 403 pp. Published by McGraw-Hill Book Co., New York, 1957. $6.50.*

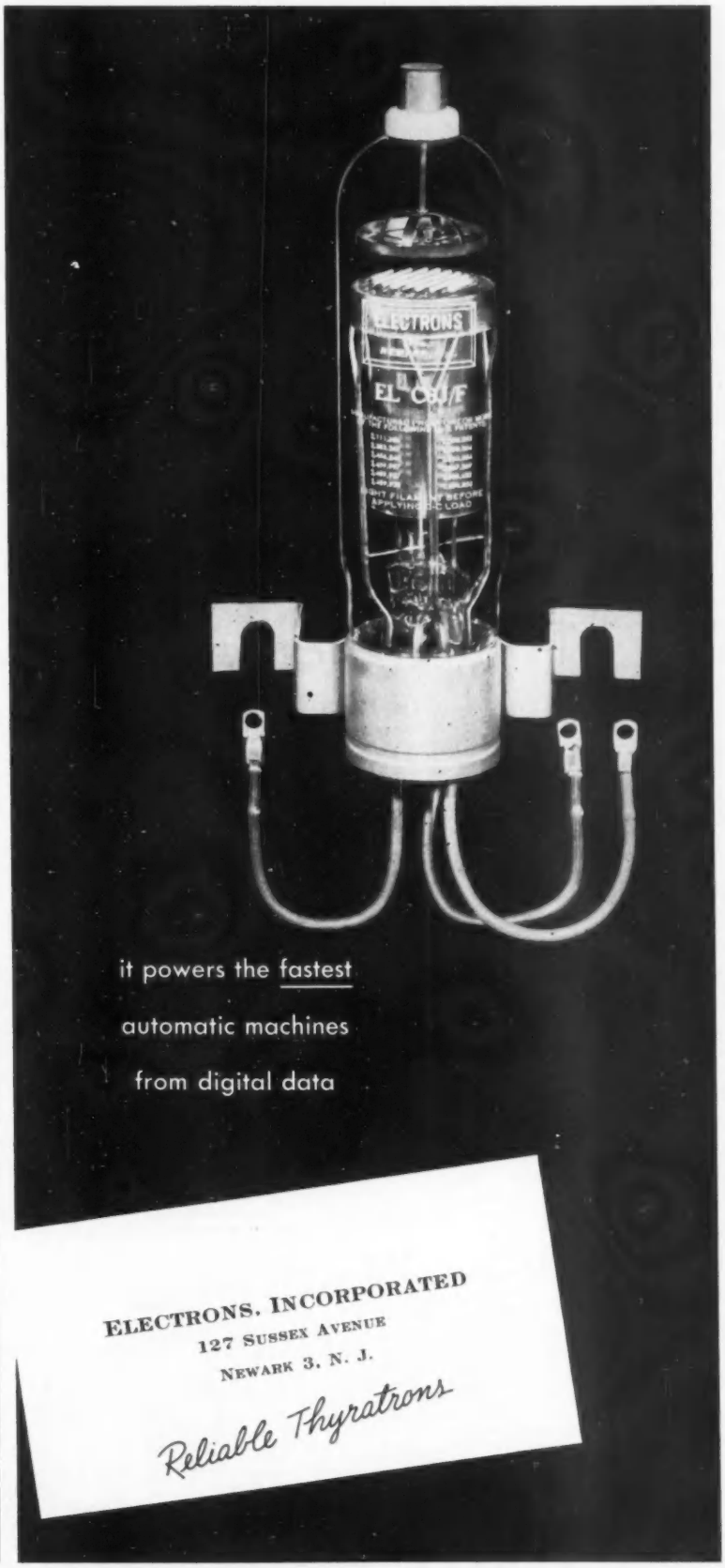
The author's somewhat contradictory open statements ("Perhaps the most important development that has ever occurred in business management is the advent of the electronic digital computer"; and: "— surprisingly little is really known, in terms of actual operating experience, about using such machines for business problems") point up the difficulties of producing anything on the subject at this time as ambitious as a guide to management. The portions of the book which may be considered to constitute "guidance" (Chapters 1, 9-12) occupy some 80 of the close to 400 pages of text. Discussed in these chapters are such matters as a look at the future and a suggested program for reaching decisions.

The major portions of the book treat digital computer "hardware" elements on a comparative basis, offer what amounts to an indoctrination in programming, and present 11 case histories. The sections dealing with input, output, storage, arithmetic, and logic are extremely lucid, and the data given on speeds, capacities and media should be extremely useful to anyone involved in equipment evaluation.

A great deal of confusion exsists generally about programming and the work of programmers. The interested reader will find in this book enough material to give a workable understanding of a complex subject. It is interesting that the three machines, Univac I, IBM 702, and Marchant MINIAC, on which the same autocorrelation problem was programmed, have been either superseded or discontinued. The rapid pace of progress in this field also takes its toll in connection with the many pictorial illustrations. At least a dozen of the equipments pictured are no longer in production.

The case histories of early installations, (Univac I at General Electric (Appliance Park) and Metropolitan Life Insurance Co., IBM 701 at Lockheed Aircraft Corp., IBM 702 at Chrysler, etc.), are given in proper perspective. Bell may have minimized some of the difficulties in the pioneer installations, but the general effect is objective and fair.

The title suggests that the book be



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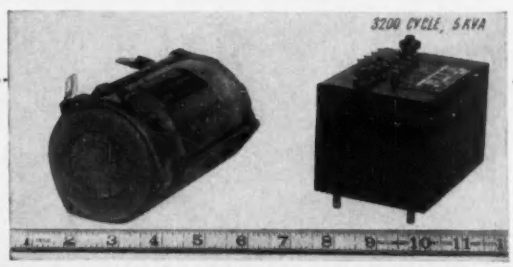

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2.5	1	5¼"	3⅛"	7.#	2.5"	3.5"	5"	4#
3.75	1	5¼"	3⅞"	9.#	2.5"	3.5"	5"	4#
3.5	2	4⅞"	5⅛"	8.25#	2.5"	3.5"	5"	4#
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NEW BOOKS

considered a guide for management. There are, of course, some advantages in reducing clerical costs and speeding clerical operations by means of electronic data processing equipment, but, says the author, the major advantage would be in more effective management control. In the section, "A Look at the Future", there is a vivid description of the "manager of tomorrow" who turns out to be a high-level, considered a guide for management. overriding supervisory control console operator with a finger on the pulse of all operations in the "real-time" system. No mention is made of the type of equipment and its cost, or the complexities of programming and the necessary programming decisions.

Based on experience, to-date, it seems that equipment costs for a "real-time" on-line management control system may well be astronomical. And it is extremely doubtful that the responsible business manager would consent to abdicating some of his basic responsibilities to mere machinery, especially where complex decisions, with profound consequences, must be made. To the extent that he understands and participates in programming a system, a manager may accept machine decisions. But he is more likely to accept them if they are minor, and will usually cross check the consequential decisions, basing his judgments on factors outside as well as inside the system. The manager, unlike the pilot of the supersonic jet, will be influenced by information beyond that shown on his instruments.

—*James Gibbons*

When Science Was an Art

NATURAL MAGICK, *John Baptista Porta, 409 pp. Published by Basic Books, Inc., New York, 1957. $7.50*

This 16th-century survey of the natural sciences, written almost 100 years before Newton, contains little information about control systems—but some fascinating tips on how "To Tincture Silver into Gold" or "How to Remedy the Softness of Tin, and the Creaking Noise That It Makes". Certainly instrument designers won't build many relays from the information reported in "Of Pneumatick Experiments", nor will "Out of the Chaos" help missile engineers to make sense out of government specs.

But John Baptista Porta's book unrolls an interesting picture of Renaissance science. It was more widely read in its day than most scientific journals are today: the book ran through edi-

tions in Spanish, French, Arabic, Italian and Dutch. The present edition, a facsimile of a 17th-century English translation, is the first volume in Basic Books' *Collector's Series in Science*; the second, William Gilbert's *De Magnete*—"On Magnets"—is due in early Fall.

For the Computer Designer

DIGITAL COMPUTER COMPONENTS AND CIRCUITS. *R. K. Richards. Published by D. Van Nostrand Co., Inc., Princeton, N. J. December 1957. $10.75. 511 pp.*

Intended as a companion book to the author's *Arithmetic Operations in Digital Computers* (published in 1955), this volume provides the engineer with information needed to reduce ideas on arithmetic and logic to the language of a machine. Throughout, the book emphasizes digital concepts rather than detailed design techniques. As the author points out, the rapid growth of computer art has in many cases made design details obsolete overnight. Fundamental concepts, on the other hand, are far less subject to change.

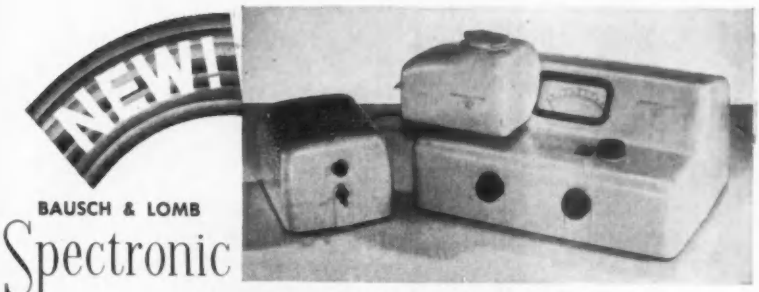
Well-organized and thoroughly referenced, the text makes no great demands on the reader's background. A reasonable familiarity with electrical and electronic fundamentals is all that is required. This is an excellent feature of the book. It affords the novice an opportunity to catch up with his more experienced colleagues in a rapidly changing field. And it provides the experienced computer designer with a one-volume reference to material that would otherwise take many months to accumulate.

Know Your Process

PROCESS ENGINEERING IN THE FOOD INDUSTRIES. *R. J. Clarke. Published by Philosophical Library, Inc., New York, 1957. 355 pp. $10.00.*

Written primarily for plant management and those responsible for improving performance of food-industry processes, this book also serves to introduce the field to control engineers.

Fluid flow, heat exchange, filtration, evaporation, distillation, extraction, crystallization, and many other subjects are described in detail. The author has considered each process or operation under three headings: general principles (based on purpose, mechanism, rate factors, methods, and horsepower required); equipment (classifying the instruments according to plants that use them); and equipment descriptions.



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MAY

Instrument Society of America, Fourth National Flight Test Instrumentation Symposium; theme: "More Data per Dollar", Park Sheraton Hotel, New York May 4-7

Institute of Radio Engineers, Western Joint Computer Conference, cosponsored by AIEE and ACM, Hotel Ambassador, Los Angeles May 6-9

American Material Handling Society, 1958 Western Material Handling Show, Los Angeles May 8-10

Instrument Society of America, Fourth National Symposium on Instrumental Methods of Analysis, Shamrock-Hilton Hotel, Houston May 12-14

Institute of Radio Engineers, National Aeronautical and Navigational Electronics Conference, Hotel Biltmore, Dayton, Ohio May 12-14

American Institute of Electrical Engineers, Materials Handling Conference, Pittsburgh, Pa. May 19-20

Instrument Society of America, National Conference on Power Systems Instrumentation and Control, New York May 21-23

Second Electronic Industries Association Conference on Maintainability of Electronic Equipment, University of Pennsylvania, Pittsburgh May 27-28

JUNE

Sixth National Telemetering Conference, sponsored by AIEE, ISA, ARS, IAS, Lord Baltimore Hotel, Baltimore, Md. June 2-4

Automation and Computer Conference, University of Texas, Austin, Texas. June 2-4

Canadian Computer Conference, University of Toronto, Toronto, Canada June 9-10

American Society of Mechanical Engineers, National Conference on Materials Handling, Public Auditorium, Cleveland, Ohio June 9-12

Fourth International Automation Exposition, and Military Automation Exposition, Coliseum, New York June 9-13

Association for Computing Machinery, 13th National Meeting, University of Illinois, Urbana, Ill. June 11-13

Institute of Radio Engineers, Second National Conference on Military Electronics, Sheraton-Park Hotel, Washington, D. C. June 16-18

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WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

Selecting and Applying Control Timers, 24 pp. A compilation of four articles including a tabular description of timer functional parts, criteria for selecting and applying control timers, a tabular listing of available timer types and their characteristics, and techniques for custom-designing controllers for time-based routines. 50 cents.

What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources are listed. 20 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems, 72 pp. This complete series covers 31 domestic and foreign systems. Detailed operational and

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performance characteristics of each system are discussed. Individual parts of series are also available as listed below. $1.25.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—III, March 1958, 16 pp. Includes detailed descriptions of nine machine tool control systems. 40 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—II, February 1958, 24 pp. Includes detailed descriptions of ten machine tool control systems. 50 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—I, January 1958, 32 pp. Includes detailed descriptions of twelve machine tool control systems. 60 cents.

Ready Reference Data Files, 24 pp. A must for every control engineer's library. Includes the first 12 data files published in Control Engineering—a diversity of topics, from system reliability through the cost of industrial temperature-measuring systems. Each one gives a method of solving a particular problem. 50 cents.

Servo Modulators—Their Application, Characteristics, and Availability, 36 pp. A group of four integrated articles covering all phases of electromechanical, electronic, solid-state, and magnetic modulators. Typical circuit diagrams, characteristics, and applications are given for each type, plus an 84-item bibliography and tables listing commercial units. 65 cents.

The Use of Digital Computers in Science, in Business, and in Control, 112 pp. A collection of 14 articles published over a period of two years as the Digital Application Series. Prominent authorities cover the application, programming, overall system design, and commercial availability of digital computers in all phases of business, industry, and the military. $3.

Analysis Instrumentation — II — Refractometers, Infrared Analyzers, Photometric Analyzers, Colorimetry, 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

Analysis Instrumentation — I — Nuclear Magnetic Resonance, Chromatography, Radioactivity, 32 pp. This reprint consists of the first four articles of the Analysis Instrumentation Series: a general introduction to set the stage, and detailed discussions of the three analysis techniques. Emphasis is on basic principles, practical tips, and the use of these techniques in automatic process control. 60 cents.

Basic Data on Process Control, 24 pp. A grouping of five articles on flow-process control, including: Basic Concepts of Feedback Control, Selecting Loops for Critical Control, Direct or Reverse Controller Actions, Modifying Valve Characteristics to Fit the Process, and Using Capacitance for Accurate Level Measurement. Practical information for every process control engineer. 50 cents.

How to Simulate Dead Time, 6 pp. Three tricky techniques for simulating dead time or transport lag. One's electronic, another is pneumatic-mechanical, and the third uses magnetic tape. A useful reference for control engineers concerned with process simulation. 15 cents.

Transistor and Thyratron Power Amplifiers, 28 pp. These three articles—one on transistors and two on thyratrons—were

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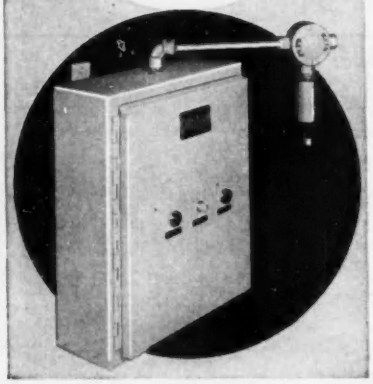

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A Functional Analysis of Automatic Logging Systems, February 1956, 16 pp. An examination of the various techniques and equipment used in performing the eight functions in a generalized automatic logging system: transducing, scale-factor correction and linearizing, derivation of quantities, scanning, analog-to-digital conversion, programming and control, alarm, and recording or logging. 50 cents.

Automatic Machining—A view and a Preview, 24 pp. A quick look at some of the newer techniques that are being used to control machine tools. It deals primarily with recorded-information (numerical) control, discussing ways to automatically furnish machining instructions, ways to drive the tool, or workpiece, and ways to measure position and size. 50 cents.

A Systems Analysis Predicts Performance, June 1955, 16 pp. This rare case history shows how determining the dynamic characteristics of both the process and the control system (and considering both open to modification) can reduce cost and improve performance. 50 cents.

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Sampled-Data Systems—No. 10, February 1957, 8 pp. Reviews the basic theory of sampled-data system analysis and synthesis, includes a reference list and an example. 25 cents.

Analog-to-Digital Converters—What Ones are Available and How They are Used—No. 11, April 1957, 12 pp. Describes techniques and lists commercial devices. 25 cents.

Fitting the Digital Computer into Process Control—No. 12, June 1957, 8 pp. Outlines a systematic approach to applying digital computers as process controllers and illustrates with a case in point. 25 cents.

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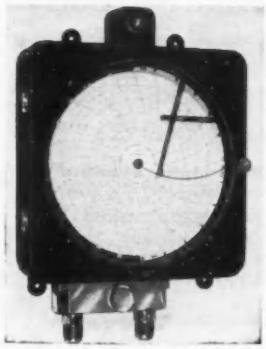

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Programming the Computer—No. 12, March 1957, 6 pp. Discusses the fundamentals of digital computer programming. 25 cents.

Checking Techniques for Digital Computers—No. 13, May 1957, 4 pp. Describes the principle of redundancy in checking and error detecting codes. 25 cents.

Tearsheets of most of the other Basic Digital and Digital Application Series articles are also available at a cost of 15 cents per article.

CONTROL BITS

Requests for hotel accommodations at the Belgian World's Fair are getting quick action through an electronic data processing system. Fair officials have already started operating a IBM Cardatype machine at the Brussels Central Railroad station. The machine checks the availability of 50,000 catalogued rooms, indicates availability, writes a lodgin voucher, and bills the applicant—all in 15 sec.

•

Collins Radio is developing a transistorized airborne doppler navigation system for airline use. First deliveries are scheduled for early 1959, production deliveries later in the year.

•

American engineering colleges are carrying nearly half of government sponsored basic research in the U. S. American Society of Engineering Education says colleges are conducting engineering research valued at $100 million per year. The campuses could accommodate another $10 million in research immediately with present staffs.

•

Burroughs Corp. is building $37,300,000 worth of electronic guidance computers for the Atlas intercontinental ballistic missile. The ground-based equipment will receive the planned trajectory prior to missile launching. During initial stages of flight, the computer will compare missile's actual course, speed, and altitude with that programmed in advance, prepare instructions to put the missile back on its predetermined course.

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Soviets are building a remote-controlled coal mine in the Donets coal

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(Continued on pages 192 & 193)

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CONTROL BITS

basin. According to Soviet news reports, all coal cutting and handling equipment will be controlled from a single panel on the surface. No miners will work at the coal face. The newspaper added that operations from moving up cutting machines to coal haulage (on belt conveyors) will be done automatically, directed by a single operator who watches the machinery on a closed television circuit.

•

American Society of Tool Engineers has completed a preliminary study of industry opinion on numerically controlled machine tools. Conclusion reached: tool engineers want to know more about numerical control. Many, the study reports, aren't familiar with the various systems or how they operate. Those who were familiar with the systems regarded short-run production as the area that programmed tools would serve best.

•

Olivetti, the Italian-firm that has won a reputation in the U.S. for its typewriters, is getting set to produce a digital computer; it will be the first commercially manufactured in Italy. Olivetti's unit, it is reported, will be about the size of an IBM 705.

•

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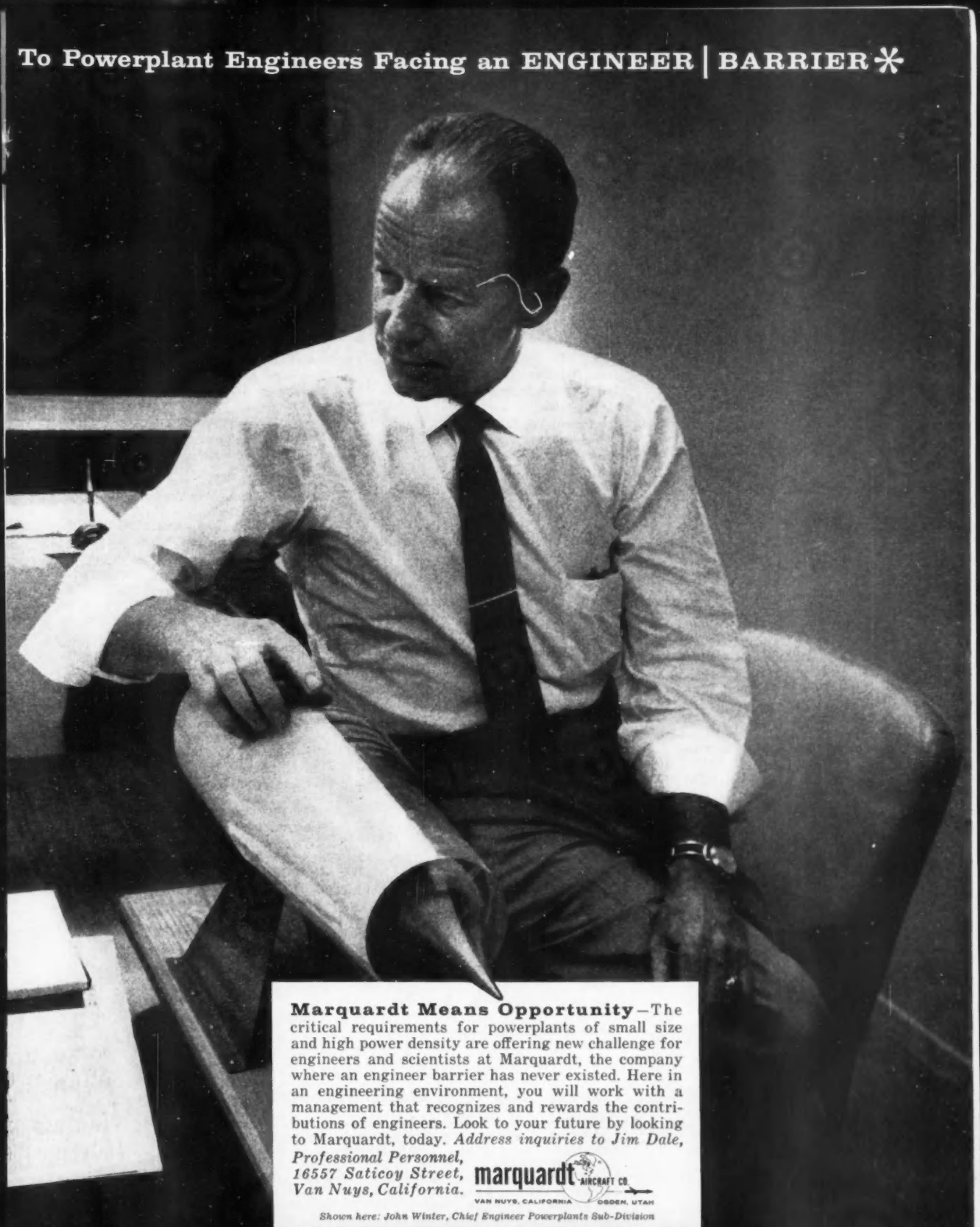

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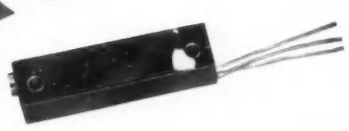

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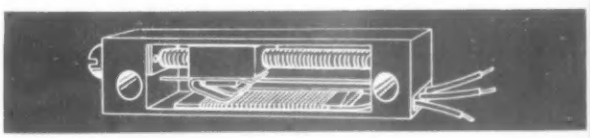

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